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TEST AND EVALUATION OF CATEGORY III ILS GROUND GUIDANCE EQUIPMENT "STAN-38 GLIDE SLOPE TESTS AT NAFEC ON RUNWAY 4"

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16. Abstract

A STAN-38 glide slope system in an M-array without clearance configuration was installed on runway 4 at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, under a joint U.S./FAA and U.K./DTI work agreement. The system was tested for conformance to ICAO Annex 10 Category III ILS specifications for system performance and stability, and for monitor performance with amplitude and phase errors in the antenna system. The effects of prevailing weather conditions on the executive monitor system were recorded. It was concluded that the primary performance characteristics met ICAO specifications, and that the executive monitor system using specified alarm limits for the test provided satisfactory alarms during degraded performance conditions except in the dephased upper antenna fault condition.

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INTRODUCTION

Purpose

The purpose of this project was to install a STAN 37/38 Instrument Landing System (ILS) at the National Aviation Facilities Experimental Center (NAFEC) and to evaluate the performance of the executive monitor system under conditions of transmitter antenna malfunction and external environmental factors, such as overflights. Tests were also conducted to establish that the characteristics of the system met the International Civil Aviation Organization (ICAO) Annex 10 Category III ILS requirements. This report covers the tests performed on the STAN 38 glide slope portion of the United Kingdom (U.K.) Category III ILS, while it was installed near the approach end of runway 04 at NAFEC. A separate report covering the STAN-37 localizer tests on runway 04 has been prepared.

Background

The evaluation of an advanced ILS for operation to Category III standards at major civil airports within the United Kingdom is being performed by the Director General of Telecommunications of the U.K. National Air Traffic Services (NATS). This type of ILS, the STAN 37/38 system, has been designed to meet stringent performance and safety requirements which have been progressively developed over recent years by ICAO and national administrations such as Federal Aviation Administration (FAA) and NATS. The overall evaluation of such an ILS is a rigorous task and requires separate identifiable subtest programs. One of these, namely, Monitor System Evaluation, is being carried out by NAFEC under a joint U.S./U.K. agreement. The work statement of the joint agreement is presented in Appendix A. A subsequent revision of this agreement (Appendix B) included planning towards operational evaluations on runway 13. This effort will be described in another report.

Operational Requirements: With the advent of new aircraft and modern flight control systems, the goal of all-weather landing as a regularly scheduled operation moves closer to reality. To successfully demonstrate Category III flight operations, a ground guidance system meeting or exceeding ICAO specifications is required. Immediate needs are for a system to be utilized in operational evaluations. The longer-range goals are to develop specifications for a prototype system and for a detailed selection order. The work to date, in the United States, has progressed along functional lines whereby component testing has been accomplished with a view towards eventual integration into a total operational system. Negotiations with the U.K./Board of Trade, presently renamed Department of Trade and Industry (DTI), have culminated in an agreement for a joint evaluation of localizer and glide slope equipments of British manufacture designated STAN 37 and STAN 38, respectively. The equipment has been built so as to meet NATS performance, safety, and integrity specifications for ILS Category III. The U.K. DTI presently (1971) has two such systems under evaluation in fully operational conditions at airports in the United Kingdom as well

as one system operating in a fully controlled environment. These U.K. tests are designed to obtain information on the reliability and availability of the system as well as to gather data on its technical performance. Additionally, the United Kingdom is analyzing information from seven other systems to establish individual unit performance. The tests at NAFEC can be considered a step towards a pooling of resources and should prove to be of mutual benefit for both countries.

Technical Requirements: Detailed requirements are spelled out in ICAO Aeronautical Telecommunications, Annex 10. In general, a ground guidance system is required which will:

1. Have course characteristics sufficient for use in Category III conditions.

2. Not be interrupted in operational usage by overflight interference.

3. Have freedom from ground and obstacle reflections to a degree sufficient to provide (1) above.

4. Provide satisfactory airborne continuity of service not deteriorated by internal switching and independent of the power source.

5. Provide sufficient and reliable monitoring to detect out-of-limit operation of critical parameters and provide appropriate logic networks for executive action.

6. Provide fail-operational ground equipment reliability.

The NATS specifications for Glide Path Type STAN-38 as listed in Telecommunications Technical Handbook 309, Vol. 3 (HB 1268/2-A, Issue 1, AL.17, May 1971) are as follows:

1. Range and Coverage - At least 10 nmi within the sectors, 8° either side of the course line bounded by upper and lower planes 1.75θ and 0.30θ respectively, above the horizontal (θ represents the glide path angle).

2. Frequency Coverage - 328.6 to 335.4 MHz.

3. Stability - Crystal controlled ±0.0002 percent over the temperature range +10°C to +50°C.

4. Polarization - Horizontal.

5. Modulation Stability - 90 Hz and 150 Hz better than ±0.01 percent.

6. Harmonic Content - Not exceeding 5 percent each tone.

7. Modulation Depth - 37.5 percent to 42.5 percent.

8. Phase Locking - Mechanical

9. Glide Path Angle - Can be set between 2° and 4° elevation.

10. Power - 200 to 250 Vac ±6 percent tolerance single phase @ 45 Hz to 450 Hz. Normal running load is 650 VA and max. of 1.5 kVA.

11. Monitoring[1] - Alarm is actuated when:

a. RF level changes -3± 0.5dB to +5.5±2.5dB.
b. Mod. sum changes ±4 percent in 80 percent.
c. Glide path angle change as detected by a change of DDM from 0 percent to 4 percent DDM.
d. Glide path width change as detected by a change of ±3 percent from a width DDM of 13 percent. The effects of glide path angle changes can be subtracted from the effects of glide path width changes.

12. Warning - Warning circuit is actuated when changes approach alarm level and for:

a. ±0.5 percent change in modulation tone frequency.
b. Failure of mains supply or battery charging.

13. Standby Switching - Automatic switching in less than one second.

Description of Equipment: The STAN-38 Glide Path equipment installed at NAFEC was a three-element, modified type M quadrature clearance array (Figure 1) without quadrature clearance, since system weaknesses may be more serious in the M-only configuration. This type of array is intended for use at sites having level terrain in front of the antenna with steadily rising terrain or building obstructions in the approach zone. Other arrays which can be provided are a two-element null reference type, the standard array for average to good sites, and a two-element sideband reference type which is intended for use at sites having level terrain in front of the antenna with abrupt downward changes in terrain in the approach zone.

A small building, called a Portakabin van, houses the glide path transmitter cabinet and ancillary equipment, and is located 10 feet or less from the glide path mast (Figure 2). The cabinet is free standing

[1] Alarm limits used for tests were ±1 percent DDM for glide path angle changes and ±1.5 percent DDM from 13 percent DDM for glide path width changes.

and has internal framework to accomodate the plug-in units, with other units being rigidly mounted inside the cabinet (Figures 3 through 6). The rigidly attached units include the following:

2 mechanical modulator units
2 RF distribution units
1 coaxial distribution unit

The plug-in units include the following:

1 common control unit
2 transmitter units
2 motor drive units
4 alarm units
4 position monitor units
4 width monitor units

The installation incorporates main and standby transmitting equipment to provide continuity of service in the event of equipment failure. The radiated signals are continuously checked by a triplicated monitoring system (two external and one internal) which initiates automatic changeover to the standby system in the event of failure of the main system. The external monitors are shown in Figure 7. A remote control unit is normally installed in the control tower. The equipment is completely solid state, except for the mechanical modulators, and utilizes strip-line RF bridges. A floating battery supply system (Figures 8 and 9) provides continuity of service for at least two hours after a main supply failure. The batteries and the charger unit are housed in a battery room inside the Portakabin van. Weights and dimensions of the equipment are as follows:

	Height (in)	Width (in)	Depth (in)	Weight (lbs)
Glide Path Cabinet	76.	28.5	27.25	1,000.
Transmitter Batteries (48 Cells)	9.75	4.75	5.25	16.
Monitor Batteries (48 Cells)	9.75	3.25	5.25	10.5
Battery Charger Unit	25.	15.	17.5	206.
Fused Isolator Switch Unit	9.	18.	8.5	20.5
Remote Control Unit	7.	19.	11.5	11.

Theory of Operation: A block diagram for the type M glide path system is shown in Figure 10.

RF Generation - Although the installation consists of a main and standby system, only one channel is considered in the following explanation. A simplified block diagram of the RF generation and distribution system is shown in Figure 11. The RF distribution unit divides the transmitter

output into two parts. One part is passed through a phase-delay circuit and the other part is applied to the mechanical modulator. The modulator power outputs are fed back to the RF distribution unit when they are combined with the unmodulated RF transmitter output to form the following signals:

1. Course CSB - A double sideband plus carrier signal with the sidebands separated from the carrier frequency by 90 Hz and 150 Hz. The mean frequency components of the sidebands are in phase with the RF carrier.

2. Course SBO - A double sideband signal without the carrier, with the sidebands separated from the transmitter frequency by 90 Hz and 150 Hz. The mean frequency components of the 150-Hz sidebands are 180° out-of-phase with the mean frequency components of the 90-Hz sidebands, and the 150-Hz sidebands are in RF phase with the carrier of the course CSB signal.

The coaxial distribution unit accepts the two or three modulated RF outputs and applies the required set of outputs direct to the null-reference array, or to an aerial distribution unit for the sideband reference and the quadrature clearance (type M) arrays. Also, facilities for changeover and internal monitoring are provided inside the coaxial distribution unit. The aerial distribution unit (Figure 12) combines the course CSB, and the course SBO, signals in correct proportions for each antenna.

Antenna Array - The modified type M quadrature clearance array requires three antennas, mounted at heights h, 2h, and 3h above the ground, where h is calculated from the equation:

$$h = \frac{\lambda}{4 \sin \theta}$$

where θ is the required glide path angle and λ is the wavelength. Each antenna is made up of six dipoles mounted on a weatherproof metal box which contains a power divider unit. All six dipoles have in-phase inputs, but the drive to the center dipoles is greater than that to the outer dipoles in the ratio of 2.4:1. The azimuth pattern consists of a major forward lobe, two minor side lobes and a reverse lobe. The front-to-back ratio of the antenna is about 24 dB, and the ratio of the side lobes is about 22 dB. The major null occurs at $\pm 40°$ about the centerline, and the 3-dB points are at $\pm 14°$ about the centerline. An advantage of using narrow beamwidth antennas is the improvement in system performance resulting from reduced susceptibility to reflection.

Proportions of the course CSB and course SBO signals are fed to each antenna in order to form the glide path radiation pattern with the minimum of interference from obstructions and rising ground lying

directly in the glide path field. The course CSB signal is fed to the lower and middle antennas with the amplitude of the lower antenna signal being twice that, and 180° out-of-phase with, the middle antenna signal. The resultant course CSB pattern (Figure 13) has low values at low elevations and rises to a maximum at 1.3θ. The course SBO signal is fed to all three antennas. The upper and lower antennas are fed signals that are one-half the amplitude of, and 180° out-of-phase with, the middle antenna signal. The resultant course SBO pattern (Figure 14) has low values at low elevations, with the first lobe maximum at 0.7θ, a null at the glide path angle (θ), and a second lobe maximum at 1.6θ. The resultant DDM is the difference in the magnitudes of the course CSB and SBO sidebands. The signal distribution to the antennas is summarized in Table 1.

Monitoring - The glide path equipment performance is checked continuously by internal and external monitors. The external monitors are duplicated, and with one internal monitor, initiate automatic main to standby equipment changeover if two out of three monitors indicate an alarm condition. A warning signal is provided when any of the monitored circuit parameters reach 80 percent of the alarm limit. A block diagram for the main equipment monitor system is shown in Figure 15. All of the monitor units are fed with RF signals. The external monitors for position and width information have two near-field 1 (NF-1) and two near-field 2 (NF-2) monitor probes above and below the glide path at 1.15θ and 0.92θ, respectively.

Monitor Sets - Each monitor set consists of two monitor units operating in conjunction with an alarm unit. Each monitor unit produces dc levels proportional to RF level, MOD SUM, and DDM, any of which can be selected and fed to the associated alarm unit. Any outut from the two monitor units may be selected and displayed on an alarm unit meter. The position output is set for zero percent DDM and the width is set for 13 percent DDM (150 Hz). Selection circuits in each monitor unit also provide dc levels which are proportional to the largest of the three positive or negative errors in the measured parameters. The error voltages are fed to the alarm unit for alarm or warning indication dependent upon the error voltage level.

Internal Monitor - The main internal monitor set utilizes four probes in the coaxial distribution unit for position and width. Three probes are used to monitor course CSB and course SBO for glide path width, and one probe monitors course CSB for glide path position. Another monitor set is used for the standby equipment and obtains monitor information similarly to the main internal monitor.

External Near Field Monitor - Each near-field monitor for position and width has two probes positioned vertically on a mast, above and below the glide path, at the 5 percent DDM points. The mast has an overall height of 22 feet. To separate the position and width information for the NF-1 and NF-2 monitor units, a monitor combining unit containing three bridges and a phasing network is used (Figure 12). It is mounted near the bottom of the monitor mast (Figure 7).

TABLE 1. - ANTENNA SIGNAL DISTRIBUTION

SIGNAL	LOWER		MIDDLE		UPPER	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
COURSE CSB						
CARRIER	1.0	0°	0.5	180°	-	-
90-Hz SIDEBAND	0.4	0°	0.2	180°	-	-
150-Hz SIDEBAND	0.4	0°	0.2	180°	-	-
COURSE SBO						
90-Hz SIDEBAND	0.071	0°	0.142	180°	0.07	0°
150-Hz SIDEBAND	0.071	180°	0.142	0°	0.071	180°

In the type-M system, the NF-1 and NF-2 position and width monitor masts are sited at the points where the middle to lower antenna phase is 135°. The monitors are displaced from a line passing through the base of the transmitter mast and parallel to the runway to provide monitor separation with differing distances to preclude signal shadowing. NF-1 monitors are displaced towards the runway centerline and NF-2 monitors are displaced away from the runway centerline. The offset distances are chosen such that the azimuth angle subtended by the monitors from the transmitting antenna mast does not exceed 10°. For an offset distance of 450 ft between transmitter mast and runway centerline, and an offset distance of 20 ft between each monitor and the line through the transmitter mast parallel to the runway, the distance of NF-1 and NF-2 from the transmitter mast is 256 and 280 ft, respectively., for a 3° glide path.

Remote Control Unit - The unit is a standard 19-in rack mounting unit incorporating five-key switches, a key controlled master switch, an audible alarm unit, and 18 semaphore (normal or alarm) indicators. The key switches are used to control the glide path equipment for the following function:

1. Equipment ON and RESET

2. Equipment OFF

3. Equipment CHANGE/OVER

4. Monitor DELAY IN

A fifth key switch is for an alarm cancelling circuit to cancel the aural alarms from the NF-2 monitor set due to interference from overflying aircraft. Visual indications of the transmitting and monitoring equipment status (normal, warning, alarm) are shown on the semaphore indicators. An interlocking feature is available to prohibit simultaneous operation or accidental shutdown of operational equipment when two glide path equipments are installed at opposite ends of a runway.

Battery Operation - Six battery banks of lead/acid cells are used to provide emergency power for a minimum period of 2 hours in the event of a mains supply failure. Each cell receives a stabilized charging voltage of 2.25 volts. A fused isolation switch unit provides isolation between the equipment and supplies, and allows the batteries to be charged by the battery chargers without the equipment being connected. Four battery banks of 12 cells each supply a load current of 750 mA at 24 volts to the four monitors (Figure 9). Two battery banks of 24 cells each supply a load current of 6 amperes at 48 volts to each transmitter (Figure 8). The expected cell life is 10 years with operation at ambient temperatures between 0°C and 55°C and relative humidity not greater than 95 percent.

Four battery charger units float charge the six equipment batteries. Individual failure warning is supplied to the remote control unit position. Automatic overload protection operates at 115 percent of full load and limits the short-circuit current to less than 120 percent of full-load current.

DISCUSSION

Test Objectives

The evaluation was conducted with the following objectives in mind:

1. Investigate the capability of the monitor system in detecting and acting upon significant changes in performance.

2. Identify and report on deficiencies and, when possible, identify the cause.

In order to satisfy these objectives, tests were performed to determine the following:

1. Normal operating characteristics.

2. Monitor system operation under degraded performance conditions.

Specific tasks for each test were formulated under a joint agreement between U.K./DTI and U.S./FAA representatives, and are listed in Appendices A and B.

Installation

A 50-foot glide-slope antenna mast was installed on a reinforced concrete pad offset 450 feet from the runway centerline and 1,219 feet from threshold (Figure 16). The terrain is relatively flat in this region and is considered a "good" site for a glide-slope installation. A higher than normal glide-path angle (3.15°) was selected in order to locate the monitor masts (22-feet in height) as far as possible from a diagonally crossing runway. This resulted in a nominal threshold crossing height of 72 feet. The recommended ICAO maximum ILS reference datum height for a Category III facility is 60 feet.

The antennas were mounted at heights of 12.71, 25.54, and 38.33 feet above the concrete pad, and were offset by 17.3, 10.8, and 4.3 inches from the mast center. A Hi-Ranger (truck-mounted boom with personnel bucket) was used for the antenna installation. The monitor antenna masts were mounted on heavy steel plates, which were anchored to the ground. Normally, the monitor masts are installed on concrete pads for maximum stability at permanent installations. It was not considered necessary for this installation since the tests were of short duration, and longer-term operational tests were planned with the system installed on runway 13.

A forklift was used to unload the Portakabin van at the site and to position it on a traprock base behind the antenna mast. The Portakabin van weighs 7,143 pounds and has overall dimensions of 23 feet long, 10-feet wide, and 9-feet high. Seven large crates contained the transmitting antennas with mounting hardware and monitor parts. One other crate was used for transporting the batteries (1,362 pounds).

The 230-volt electrical system inside the Portakabin van is an above-ground system. The ground is a separate lead and is not tied to the neutral wire. The U.S. common single-phase 230-volt, 3-wire power system has two lines at a potential of 115 volts above ground with 230 volts between the 115 volt lines. An isolation transformer is required to interface the two systems. Lines having a minimum of 25 amperes capacity are required. Approximately 24 gallons of sulfuric acid with a specific gravity of 1.210 at 60°F is required (local purchase) for the batteries. Power supplies capable of supplying charging rates up to 4A at 48 volts (equipment batteries - 2 each) and 2A at 24 volts (monitor batteries - 4 each) are required.

System Alignment

The three-element, type-M array (without clearance signals) was aligned in accordance with specified procedures under the supervision of U.K./DTI technical personnel and included the following:

1. RF Combining Bridge Alignment

   (a) Course Alignment - B[2]
   (b) Course Alignment - A[2]

2. Modulator Alignment - A and B

3. Phasing and Power Ratio Setting - A

4. Internal Aerial Monitor Alignment - A

5. Alignment of B

6. Carrier Suppression Measurement - A and B

7. Modulator Distortion Measurement - A and B

8. External Phasing - A

   (a) Lower Aerial Phasing
   (b) Upper Aerial Phasing

[2] B - Standby System
A - Main System

9. Monitor Set Alignment - A

   (a) NF-1 Monitor Set Alignment - A
   (b) NF-2 Monitor Set Alignment - A
   (c) Internal Load Monitor set Alignment - B

10. Common Control Unit Function Checks

11. Remote Control Unit Function Checks

12. Meter Readings

In general, the RF combining bridges are aligned for proper impedance matching on both systems. The phasing and power ratio is set up on A and the internal aerial monitor is aligned with A. Subsequently, B is operated into the antennas, and the transmitter is aligned to match the internal aerial monitor. Then, B is operated into the internal load, and the internal load monitor is aligned to match the transmitter. All external phasing is performed with A radiating into the antennas. The alignment procedure is straightforward and does not require excessive time to perform. A problem was incurred in attempting to align B to match the internal aerial monitor in that the modulation level could not be decreased to the proper level. Since the planned tests did not require normal changeover operation, the problem was ignored and A was used exclusively. The directional coupler (reflectometer) on each antenna feedline was checked with an RF voltmeter to facilitate more precise power-ratio settings. The manufacturer's accuracy was given as ± 1 dB. Appropriate correction factors were obtained and used in setting the power levels.

Test equipment used for system alignment included the following: QB.1 VSWR Indicator, Airmec 210 Modulation Meter, oscilloscope, Precision ILS Calibrator (Wayne-Kerr N-100), Field Test Monitor Set QB34, Wave Analyzer (Hewlett-Packard 302A) RF Power Meter (BIRD 43), and Boonton 91H RF Voltmeter.

The external phasing was performed utilizing the Field Test Monitor Set QB34 (Figure 17) set up on two permanent mast monitor locations at the 180° and 135° middle to lower aerial phase points. A test setup using the QB34 on the 180° point is shown in Figure 7.

The calibration of the monitor units was checked before monitor alignment using a bench setup (Figure 18) consisting of the following items: QB.11-A Two-Tone Generator Set, QB.16-A Monitor Test Rack, Hewlett-Packard 608 RF Signal Generator, and N-100 Precision ILS Calibrator. The alarm indications (± 5 divisions on the Alarm Unit meters) occurred at the following limits:

INT. AER., NF-1, NF-2 MONITOR UNITS	RF (dB)	MOD SUM (%)	DDM (%)
Position	- 1.2 to -2.2	+2.0 from 40/40	+1.0 from 0 DDM
Width	- 1.0 to -2.2	$\mp$2.0 from 40/40	$\mp$1.5 from 13% DDM

The NF-1 and NF-2 monitors were set to the external radiated signals by raising or lowering the individual dipoles on the fixed mast to align the monitors to within two divisions of zero using alarm unit indications. The position monitors were set near the 0-DDM point and the width monitors were zero set near at the 13 percent DDM point in the 150-Hz sector.

Instrumentation

Airborne: The project aircraft, N-247, was a flight inspection instrumented Convair T-29. The signals recorded on the oscillographic recorder included the following: Crosspointer Current Nos. 1, 2, and 3; Flag Current Nos. 1 and 2; AGC Nos. 1 and 2; Marker Beacon; DC Buss; Event Marks from DME, pilot, theodolite angle (1020-Hz tone). Recording sensitivities were selected to provide ±2-in. trace deflections for ±75-uA crosspointer current for structure runs, ±150-uA for path-width runs, and ±400-uA for clearance runs.

Preflight calibration was accomplished by feeding the receivers (Collins Type 51V-2) a test signal from the standard bench test set (Boonton 232A) in the Avionics Shop via a coaxial cable, and checking the recorded parameters for compliance to the following tolerances:

Crosspointer centering: 0 ±2 uA
Crosspointer deflection sensitivity: 78 ±3 uA for a 2-dB 90/150 ratio
Flag Current: 340 to 360 uA for 40/40 percent modulation (35/35 percent = 300 uA and 45/45 percent = 400 uA)

The RF level was adjusted to provide a 700 uV signal at the receiver input. If the foregoing tolerances were exceeded, the receivers were recalibrated and rechecked before the flight. A post-flight calibration similar to the preflight calibration was performed after each flight.

A cross-calibration check was performed at the Avionics Shop using the standard Boonton 232A set up (for calibration of the airborne receivers) and the ground test equipment (for system alignment). The values measured by each instrument are listed in Table 2.

Ground:

Far-Field - A 160-foot tower (Building 172) in the approach zone was used as a far-field test site for obtaining below-path DDM measurements. The tower was located 5,200 feet from the antenna on a 17° angle offset from a line through the antenna parallel to the runway. Two glide slope antennas (Collins Type 37P-4,) were mounted on the tower at elevation angles of 0.8° and 1.2° (from the glide-slope site). The signals were fed to Wilcox field detectors and monitors, which were installed in a small maintenance room at the base of the tower. A Brush 440 four-channel recorder was used for continuous recording of DDM and RF level signals from both antennas. A block diagram of the equipment is shown in Figure 19. Weekly calibrations

TABLE 2. - TEST EQUIPMENT CROSS-CALIBRATION

Avionics Shop 232-A Settings*		N-100 Readings		QB-34 Readings			
90/150 Tone Ratio	% MOD	% DDM	% MOD	% DDM	% MOD 90 Hz	% MOD 150 Hz	MOD SUM
0 dB	40/40	0.04 (150)	40.3/40.3	0.08 (150)	35.3	35.2	69.3
2 dB (90)	40/40	9.0 (90)	----	6.7 (90)	----	----	----
2 dB (150)	40/40	9.0 (150)	----	6.8 (150	----	----	----
0 dB	35/35	----	34.6/34.6	----	29.9	29.7	59.0
0 dB	45/45	----	45.9/45.9	----	39.8	39.75	78.1

* NOTES:
1. RF Level set to 25 mV for QB-34 and to 20 mV for N-100.
2. Frequency = 334.7 MHz.
3. 2 dB 90/150 tone ratio = 9.2% DDM = 78 uA deflection current

were performed using a Cossor ILS Test Set, Model CRM 555 (Figure 20). To check response at the far-field site, the MOD BAL and WIDTH controls were varied to obtain alarm-unit meter deflections on Internal Aerial Position and Width DDM monitors, respectively. The recorded values are tabulated as follows:

POSITION			WIDTH		
INT. AER. MONITOR DDM READING (meter div.)	FAR-FIELD ANTENNAS 1.2° (uA)	FAR-FIELD ANTENNAS 0.8° (uA)	INT. AER. MONITOR DDM READING (meter div.)	FAR-FIELD ANTENNAS 1.2° (uA)	FAR-FIELD ANTENNAS 0.8° (uA)
10L[3] (150 Hz predom.)	149	168	10L (Sharp)	67	85
5L	142	162	5L	110	130
0	135	155	0	127	149
5R[4]	125	145	5R	130	152
10R (90 Hz predom.)	118	139	10R (Broad)	124	142

The far-field position-change response correlation was good, but the width-change response correlation was poor. The far-field indication changed only slightly as the width was varied from normal (0 indication) to the broad-alarm limit (5R indication), and reversed as the width was broadened further (to 10R). However, the site was used to record data during the test period on a 24-hour basis for possible correlation with the near-field monitor.

<u>Portakabin</u> - The STAN-38 monitor outputs were available for recording inside the Portakabin at a wall terminal box. A six-channel Brush Mark-260 Recorder (Figure 21) was used to record the following signals:

Internal Aerial Position DDM
NF-1 Position DDM
NF-2 Position DDM
Internal Aerial WIDTH DDM
NF-1 WIDTH DDM
NF-2 WIDTH DDM

<u>Mobile Van</u> - The DDM at runway threshold was measured periodically. A Bendix Type GSA-25B Glide-Slope Receiver was utilized with a pickup antenna height of 20 feet above the ground. This location provided the prime data to determine whether the signal below the glide path remained "fly-up."

3 10 - Divisions left on Alarm Unit meter
4 5 - Divisions right on Alarm Unit meter

SUMMARY OF RESULTS

Facility performance characteristics were determined in accordance with specific tasks outlined in the U.S./U.K. Work Agreement using ICAO tolerances listed in Annex 10 for Category III as the performance criterion. System stability was checked over a 5-month period (December 1970 - May 1971). The alarm levels used for the tests were tighter than the currently specified alarm limits in Volume 3 of Handbook TTH309 (Issue 1, Amendment List 17, May 1971) which are presumably used by the United Kingdom (see section on "Technical Requirements" for actual alarm-limit values).

Primary Performance Characteristics

Path Angle and Path Structure: A radio telemetering theodolite (RTT) was used to track the aircraft from 6 nmi to the runway threshold. The radio theodolite was initially sited in accordance with Para. 217.32 9 "Theodolite Procedures" of U.S. Flight Inspection Manual OA P 8200.1 CHG 17, 8/26/70, which takes into account elevation differences between the glide-slope antenna site and the runway (opposite the antenna mast). However, placement of the RTT equipment between the transmitting antenna mast and the monitor antennas adversely affected monitor performance and, a different location at the base of the glide-slope antenna mast was used which did not result in interference. The data were corrected in a computer program which performed a translation from the actual RTT site to the U.S.F.I.M. specified site by applying a correction factor to the airborne-RTT (aircraft-deviation) data as a function of range. A pole-mounted, battery-operated marker beacon (Figure 22) was installed 3,700 feet from threshold in the approach zone for a reference point on the airborne recording, since the runway was not served by a middle marker. Resultant glide-path structures with the RTT set up at both sites were within ICAO Category III limits and are shown in Figures 23 and 24. The bend amplitudes did not exceed the allowable 20-uA (.023 percent DDM) limits.

Path Width and Linearity: An airborne recording of a level run at 1,000-foot altitude with theodolite tracking is shown in Figure 25. The angular displacement sensitivity was within the $0.12\theta \pm 0.02\theta$ ICAO specification for the 0.0875 DDM (75 uA) points above and below the glide angle. The DDM below the glide path increases smoothly to 0.22 DDM (180 uA) and is achieved at an angle above 0.45θ (1.4°) in accordance with the ICAO specification.

Clearance Below Path: The airborne recording obtained at 10 nmi on a 1,000-foot altitude run is shown in Figure 25. The receivers indicated over 300 uA crosspointer current (0.37 DDM), hidden flags (at least 240 uA F.C.), and operating AGC at 10 nmi. The elevation angle to the site was 0.97° at 10 nmi and met the ICAO requirement for the DDM to be greater than 0.22, at least down to 0.45θ.

Path Angle and Width at ±150 uA Localizer Edges: The aircraft was flown on the right and left 150 uA localizer offset courses at 1,000-foot altitude with theodolite tracking. Path angle and width values are summarized as follows:

LOCALIZER TRACK	GLIDE PATH ANGLE (deg)	0.0875 DDM UPPER (deg)	0.0875 DDM LOWER (deg)	PATH WIDTH (deg)
Centerline	3.12	3.52	2.82	0.70
175 uA (90 Hz)	3.04	3.39	2.68	0.71
155 uA (150 Hz)	3.13	3.47	2.79	0.68

The run on the 90-Hz side resulted in a localizer displacement further than the desired 150 uA, but was considered satisfactory due to time limitations. The localizer was an experimental one and was undergoing tests precluding further use for guidance purposes.

Coverage: The aircraft was flown at glide-path angles of 0.3θ (1°) and 1.75θ (6.1°) at 8° to the right and left of centerline using RTT guidance. Satisfactory receiver operation was obtained from approximately 9 to 10 nmi using DME readings at the low angles (0.3θ) and beyond 10 nmi at the high angles (1.75θ). ICAO specifies 0.45θ for the low-angle coverage requirement to 10 nmi. Time did not permit checks at 0.45θ, although runs at 0.45θ on centerline resulted in satisfactory receiver operation from beyond 10 nmi.

Stability

Flight checks were performed from December 1970 to May 1971, under various ground-terrain conditions and temperatures. A tabulation of measured glide-path angle, path width, flag current (corresponding to modulation depth), and temperature conditions is shown in Table 3. The variations did not exceed the ICAO tolerances of ±0.4θ (2.99°-3.23°) for the glide-path angle, ±0.15 of the path width (0.61°-0.83°) for the path width, and 37.5 percent - 42.5 percent depth of modulation (325 - 375 uA receiver flag current). The DDM requirement of 0.0875 (75 uA) at angular displacements above and below the glide path of 0.12θ ±0.02θ was met. The system configuration was normal during all of the runs. During the test period, other specific tests, such as dephasing and control maladjustment required configuration changes, although the controls were not always reset to normal.

Carrier frequency was measured each week from December 1970 through May 1971, and variations were well within the allowable 0.005 percent tolerance.

Fault Tests

The phase and amplitude distributions of signals feeding the antennas were maladjusted to obtain monitor-alarm levels just short of that required for system changeover (two out of three monitors in alarm) using the alarm-unit meters for error level indications. The aircraft was then used to record the radiated

TABLE 3. - PERIODIC FLIGHT CHECK RESULTS

DATE	TEMP (°F)	TERRAIN	GLIDE PATH ANGLE[1] (deg)	PATH WIDTH (deg)	LOWER 0.875DDM[1] (deg)	UPPER 0.0875DDM[1] (deg)	RECEIVER FLAG CURRENT[2] (unit)
12/29/70	32	Frozen	3.11	0.72	2.75	3.47	360
1/6/71	34	Muddy	3.12	0.72	2.78	3.50	345
1/12/71	45	Frozen	3.13	0.70	2.78	3.48	350
1/22/71	47	--	3.12	0.70	2.82	3.52	355
2/3/71	24	Frozen	3.17	0.74	2.78	3.52	--
2/25/71	49	--	3.14	0.73	2.78	3.53	335
3/11/71	46	Damp	3.13	0.71	2.79	3.50	335
4/13/71	63	Dry	3.14	0.72	2.77	3.49	325
4/14/71	52	Dry	3.17	0.73	2.79	3.52	325
4/19/71	64	Dry	3.16	0.75	2.80	3.55	325
5/14/71	70	--	3.17	0.75	2.81	3.56	340

NOTE: 1 Measured during level runs at 1,000 ft altitude with theodolite tracking.
2 Measured during modulation balance run with CR/CSB (modulated carrier) only.

signals in the far-field, while the monitor signals were measured with the N-100 ILS Calibrator inside the Portakabin. On each flight the normal station configuration was recorded first as the standard for fault-condition comparison. Monitor change, the difference between the monitor reading during a fault condition and the beginning and end readings (for a given test period) in a normal configuration, was the parameter used to assess monitor performance. The monitor meter indicators were not reset if the meter indications were within five divisions of center-zero because of time limitation factors. Internal aerial monitor response was measured only during the control maladjustment tests, since the other faults did not affect it.

Conditions under which monitors should require shutdown for Category III are outlined in ICAO Annex 10 and include the following:

1. A shift of the mean ILS glide-path angle equivalent to more than 0.075Θ from Θ.

2. A change of displacement sensitivity to a value differing more than 25 percent from the nominal value.

3. Lowering of the line beneath the ILS glide path at which a DDM of 0.0875 is realized to less than 0.7475Θ from horizontal.

The foregoing limits were used to determine whether the far-field characteristics were within Category III tolerances under fault conditions. However, the monitor alarm limits used for the tests were tighter than the alarm limits specified in Handbook TTH309 (presumably used by the United Kingdom), and far-field results may not necessarily be degraded similarly for a given alarm condition.

Phase Error Effects: Three variable phasers (±60°), Meridian Type MM3870, were calibrated using a Hewlett-Packard Vector Voltmeter. The insertion loss of each phaser and adaptors with connecting cables was 0.2 dB. The phasers were inserted in each antenna feedline between the outputs of the aerial distribution unit and the directional couplers. When the phasers were added to the feedlines, the far-field monitor indications showed a pronounced DDM change - the 1.2° channel changed from 127 to 200 uA and the 0.8° channel changed from 145 to 210 uA. Flight-check data showed that the glide angle changed from 3.15° to 3.06° and the width changed from 0.75° to 0.80°. Apparently, insertion of the phasers resulted in a mismatch causing the observed changes. The near-field position monitors changed 2-1/2 to 5 divisions to the right (90 Hz) on the alarm meters indicating a lowering of the glide path, which corresponded to the far-field measurements. The effect of phaser insertion can be seen in Figure 26 as indicated by the dashed vertical line. The three position DDM monitor indications shifted toward zero. However, the monitor readings were within the ±5 division alarm limits. During the dephasing tests, all reference or standard readings used for determining the monitor DDM change (as phasers were varied) were the values measured with the phasers inserted and set to zero. Only one phaser was varied at a time - the other two phasers remaining set at zero. Results of dephasing tests are summarized in Table 4.

TABLE 4. - RESULTS OF ANTENNA DEPHASING

PHASER ANTENNA SETTING		MONITOR READINGS: NF-1 DDM CHANGE		MONITOR READINGS: NF-2 DDM CHANGE		FLIGHT CHECK MEASUREMENTS: MEAN GLIDE ANGLE			PATH WIDTH			LOWER 0.0875 DDM IN FAULT	FALSE PATHS
		POS.	WIDTH	POS.	WIDTH	REF.	FAULT	CHANGE	REF.	FAULT	CHANGE		
	(deg)	(%)	(%)	(%)	(%)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)
Upper	+29	1.6-1.7	2.5-2.8	0.8-1.0	0.3-1.0	3.02	2.84	-0.18	0.73	0.77	+0.04	2.54	-
Upper	-39	0.6	1.5	0.9-1.0	1.0-1.5	3.04	3.17	+0.13	0.72	0.72	0.00	1.0 & 2.83	1
Middle	+8	0.1-0.4	2.6-3.1	0.1-0.3	2.0-2.5	3.02	3.02	0.00	0.76	0.78	+0.02	2.66	-
Middle	-6	0.7-1.1	1.5-2.0	0.0-0.4	1.0-1.5	3.02	3.00	+0.02	0.76	0.76	0.00	2.67	-
Lower	+9	0.7	5.5	0.4-0.5	0.5-1.0	3.03	3.05	+0.02	0.76	0.73	-0.03	2.73	-
Lower	-4	0.4-0.5	1.8-2.3	0.2-0.6	1.5	3.02	2.99	-0.03	0.74	0.77	+0.03	2.68	-

ICAO MONITOR ALARM LIMITS

Mean Glide Angle change: more than +0.075θ from θ.
Displacement Sensitivity (Path Width) change: more than +25% from nominal.
Angle of Lower 0.0875 DDM: below 0.7475θ from horizontal.

Additional dephasing data were collected with the mobile van parked at the runway threshold on centerline with the glide slope receiver antenna height set at 20 feet (about 0.84° elevation angle to the site). The receiver CDI current and flag current were recorded for the phaser settings shown in Table 4 and are tabulated with the far-field monitor readings as follows:

RECEIVER MEASUREMENTS AT RUNWAY THRESHOLD

PHASER SETTING (deg)	CDI CURRENT (uA)	FLAG CURRENT (uA)	1.2° FAR-FIELD TEST SITE DDM (uA)
0 (start)	360(150 Hz)	370	220(150 Hz)
+29U	520(150 Hz)	400	250(150 Hz)
-39U	150(90 Hz)	345	90(150 Hz)
+ 8M	125(150 Hz)	355	110(150 Hz)
- 6M	540(150 Hz)	380	250(150 Hz)
+ 9L	540(150 Hz)	390	250(150 Hz)
- 4L	270(150 Hz)	360	170(150 Hz)
0 (end)	345(150 Hz)	360	215(150 Hz)

It should be noted that the exact STAN-38 alarm limits used for this test of ± 1 percent DDM for position and ± 1.5 percent for width were not achieved during the tests (as shown in Table 4, under Monitor Readings). The reason for this is attributed partially to monitor output change from the beginning to the end of a given test period, and partially to the ± 0.5 percent DDM readability of the N-100 on the 40 percent DDM scale used for measuring the width-monitor signals.

Decreasing phase (39°) on the upper antenna resulted in a false path at an elevation angle below 1°, but with a flag showing as checked by the aircraft. However, the 0.0875 DDM point occurred at 1° without a flag (Figure 27). The truck data on the runway at threshold confirmed the presence of a false path by a 150 uA fly-down (90 Hz) CDI reading for the same dephased condition. The far-field site (1.2° antenna) showed a change of DDM from 220 uA fly-up to 90 uA fly-up.

Amplitude Error Effects: A 0 - 15 dB variable attenuator, Meridian Type MM3881, and a compensating phaser was inserted in each antenna feedline for the amplitude error tests. The attenuator, phaser, and connecting cables were calibrated for phase change with a Hewlett-Packard Vector Voltmeter before the tests. The insertion loss was 0.6 dB. Test procedures used for amplitude changes were similar to the dephasing procedures, except that the attenuator was inserted in only one feedline at a time. The test results are summarized in Table 5, and show that the measured values are within ICAO monitor-alarm tolerances. The 1.2° far-field site showed the following DDM values during the attenuation tests:

TABLE 5. - AMPLITUDE ERROR TEST RESULTS

ATTENUATION ADDED TO ANTENNA	MONITOR READINGS				FLIGHT CHECK MEASUREMENTS						
	NF-1 DDM CHANGE		NF-2 DDM CHANGE		MEAN GLIDE ANGLE			PATH WIDTH			LOWER 0.0875 DDM IN FAULT
	POS. (%)	WIDTH (%)	POS. (%)	WIDTH (%)	REF. (deg)	FAULT (deg)	CHANGE (deg)	REF. (deg)	FAULT (deg)	CHANGE (deg)	(deg)
2.0 dB (Upper)	0.2-0.4	0.5-1.0	0.6-1.3	1.0-1.8	3.10	3.15	+0.15	0.73	0.73	0.00	2.82
0.6 dB (Middle)	0.3-0.5	1.5-2.0	0.1-0.6	2.5-3.0	3.10	3.09	-0.01	0.72	0.88	+0.16	2.66
0.7 dB (Lower)	1.2-1.3	1.0-1.5	0.4-1.1	0.3-1.0	3.10	3.15	+0.05	0.72	0.68	-0.14	2.85

ICAO MONITOR ALARM LIMITS

Mean Glide Angle change: more than +0.075θ from θ.
Displacement Sensitivity (Path Width) change: more than ±25% from nominal.
Angle of Lower 0.0875 DDM: below 0.7475θ from horizontal.

Attenuation	DDM
0	165 uA
2 dB (Upper Ant.)	140
0.6 dB (Middle Ant.)	210
0.7 dB (Lower Ant.)	140

Control Maladjustment: Several controls on the aerial distribution unit and on the RF distribution unit were maladjusted to check monitor performance against changes measured in the far-field using the aircraft. Similar test procedures were used during the control maladjustment tests as were used during the dephasing and amplitude error tests. The test results are summarized in Table 6, and show that the far-field measured values are within ICAO monitor-alarm tolerances.

Weather Effects

Prevailing weather data were obtained from surface weather observation records kept by the Weather Bureau located on the airfield. The recorded Internal, NF-1 and NF-2 monitor DDM outputs were read at 2-hour intervals as were far-field site data, and were plotted on graphs as shown in Figures 26 and 28 through 32. The test period extended from February 12, 1971, when the monitor alignment was completed, until May 19, 1971, when the testing was terminated. The monitor data were read primarily for temperature change and rain/snow correlation. Short-term step function and noisy monitor output variations were not included (an average value was drawn in and read during the abnormal condition). An example of an abnormal condition is shown on the Portakabin monitor recording in Figure 33, when small birds (starlings and sparrows) were observed on the transmitting and monitor antennas. The monitor alarm limits used for the tests (as shown on the graphs) are tighter than the current alarm limits specified in Handbook TTH309, and the monitor variations would, of consequence, be effectively reduced with the current alarm limits.

The monitor variations on the graphs show a pronounced cyclic trend with temperature variations in the 20 - 40° range from the 15th through the 18th of February, when the monitor variations were of relatively large amplitude. On March 10th, the 20 - 40° temperature variation did not show the same large amplitude monitor variations, but rather were of the same order of magnitude as the variations during 30 - 50° and 40 - 60° temperature variation ranges. A possible important consideration is that the monitor installation was not a permanent one, in that the monitor masts were not anchored in concrete nor were the feedlines routed in buried ducts.

Equipment Failures

Units which were inoperative or failed to meet specifications when placed in service included the following:

TABLE 6. - CONTROL MALADJUSTMENT TEST RESULTS

MALADJUSTED CONTROL	MONITOR READINGS						FLIGHT CHECK MEASUREMENTS						
	NF-1 DDM CHANGE		NF-2 DDM CHANGE		INT AER DDM CHANGE		MEAN GLIDE ANGLE			PATH WIDTH			LOWER 0.0875 DDM IN FAULT
	POS. (%)	WIDTH (%)	POS. (%)	WIDTH (%)	POS. (%)	WIDTH (%)	REF. (deg)	FAULT (deg)	CHANGE (deg)	REF. (deg)	FAULT (deg)	CHANGE (deg)	(deg)
SBO RATIO M:U-L	0.1-0.8	1.0-1.3	0.4-1.1	1.0	-	-	3.11	3.09	-0.02	0.75	0.82	+0.07	2.73
CL & SBO RATIO U/L	0.7-0.9	0.2-0.5	0.7-0.8	1.2	-	-	3.15[1]	3.17[1]	+0.02	0.72	0.73	+0.01	2.80
WIDTH (SHARP)	0.4-0.6	0.0-0.3	0.1-0.2	1.3	0.2	1.5-2.0	3.14[1]	3.12[1]	-0.02	0.72	0.65	-0.07	2.79
WIDTH (BROAD)	0.3-0.5	0.2-0.8	0.0-0.1	1.3	0.2	0.5-1.5	3.14[1]	3.16[1]	+0.02	0.72	0.82	+0.10	2.75
MOD. BAL.[2]	>(0.5-0.9)	1.0-1.3	>(0.8-1.2)	1.0-1.2	1.1-1.3	1.2	3.13[1]	3.18[1]	+0.05	0.69	0.69	0.00	2.83

ICAO MONITOR ALARM LIMITS

Mean Glide Angle change: more than +0.075θ from θ.
Displacement Sensitivity (Path Width) change: more than ±25% from nominal.
Angle of Lower 0.0875 DDM: below 0.7475θ from horizontal.

[1] From 1000-ft level run.
[2] Monitor readings and flight check measurements obtained on different days using same monitor alarm-unit meter readings. Position DDM values were converted from alarm-unit meter readings using calibration graph and exceeded full-scale deflection (10-divisions) during fault condition on NF-1 and NF-2.

1. Alarm Units (2) - the warning and/or alarm light would not extinguish with proper signals.

2. Mechanical Modulator Unit (STANDBY EQUIPMENT) - did not meet harmonic distortion requirements.

3. Motor Drive Unit (STANDBY EQUIPMENT) - failed to start mechanical modulator when switched "on."

4. CR/SBO switch on Coaxial Distribution Unit - intermittent.

The two-alarm units and the mechanical modulator were sent back to the United Kingdom for repairs and realignment. When installed and checked after realignment, the modulator met distortion requirements. The alarm units were not received in time for the tests and were not rechecked. A new 360-Hz tuning fork was installed in the Motor Drive Unit (on STANDBY EQUIPMENT), but failed to correct the problem. The unit had to be slightly withdrawn from the cabinet and jarred in place to start the modulators. To circumvent the CR/SBO switch problem during the test, the CR/SBO relay position was checked with an oscilloscope by observing the audio waveform on a width-monitor unit output jack (to determine whether the CR/SBO was being fed to the antenna or to the internal load). An intermittent feedline connection on the coaxial distribution unit was discovered during the alignment procedures, and was corrected by replacing a ground ring on the connector.

Both transmitter units, MAIN and STANDBY, failed while in-service after about 500-hours operating time. One unit exhibited a low power output (0.2 watt) and the other unit was subject to transients and had erratic output when the equipment meter switch was operated. Both units were sent to the United Kingdom for repair. A spare transmitter unit was used in the MAIN equipment. After a 3-month operating period, the power output decreased from 18 to 12 watts and the frequency changed from 334.704970 to 334.700920 MHz on the spare unit. The RF stages were realigned and the frequency was reset. After 10 days, the power output dropped from 20 to 16 watts and the frequency changed 8.16 KHz. The two repaired transmitter units were placed in service and failed within 1-week's operation. The spare transmitter unit was repaired and realigned and operated satisfactorily for the duration of the test period (8 months).

Two monitor units were changed during the test peiod. One unit exhibited erroneous readings observed during a control maladjustment check, and the other unit indicated full-scale DDM and MOD alarm conditions with normal input signals. spare monitor units from the internal load bank were used to replace the faulty units. The tests required an abnormal amount of monitor unit removals and insertions which may have contributed to or caused the monitor unit failures.

CONCLUSIONS

1. The primary performance characteristics of the STAN-38 glide-slope equipment in the M-array without clearance configuration meet the Category III technical requirements listed in ICAO Annex 10.

NOTE: This conclusion should not be used to imply that the Federal Aviation Administration (FAA) approves of this type of glide slope configuration for use in the United States. The STAN 38 was tested against ICAO Annex 10 specifications and not specific FAA Standards. FAA always requires a separate clearance signal with its M-array glide slopes.

2. The glide slope transmitting system provides path stability and quality suitable for Category III use.

3. The STAN-38 executive monitor system performed adequately under conditions of degraded system performance as measured in the far field, except during the dephased (39°) upper antenna fault condition when a false path occurred below 1°.

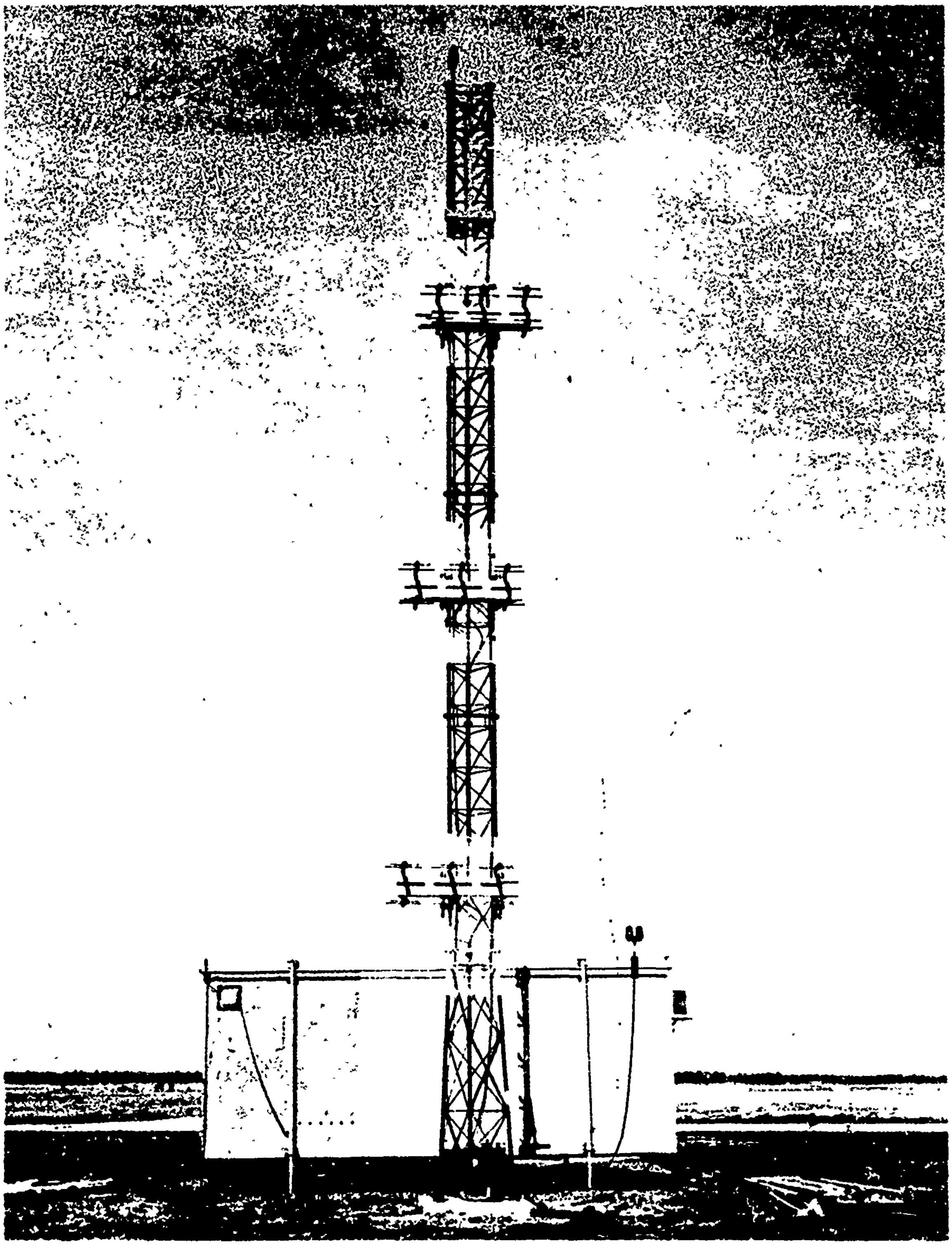

FIGURE 1 - STAN-38 TYPE-M ARRAY WITH PORTAKABIN VAN - FRONT VIEW

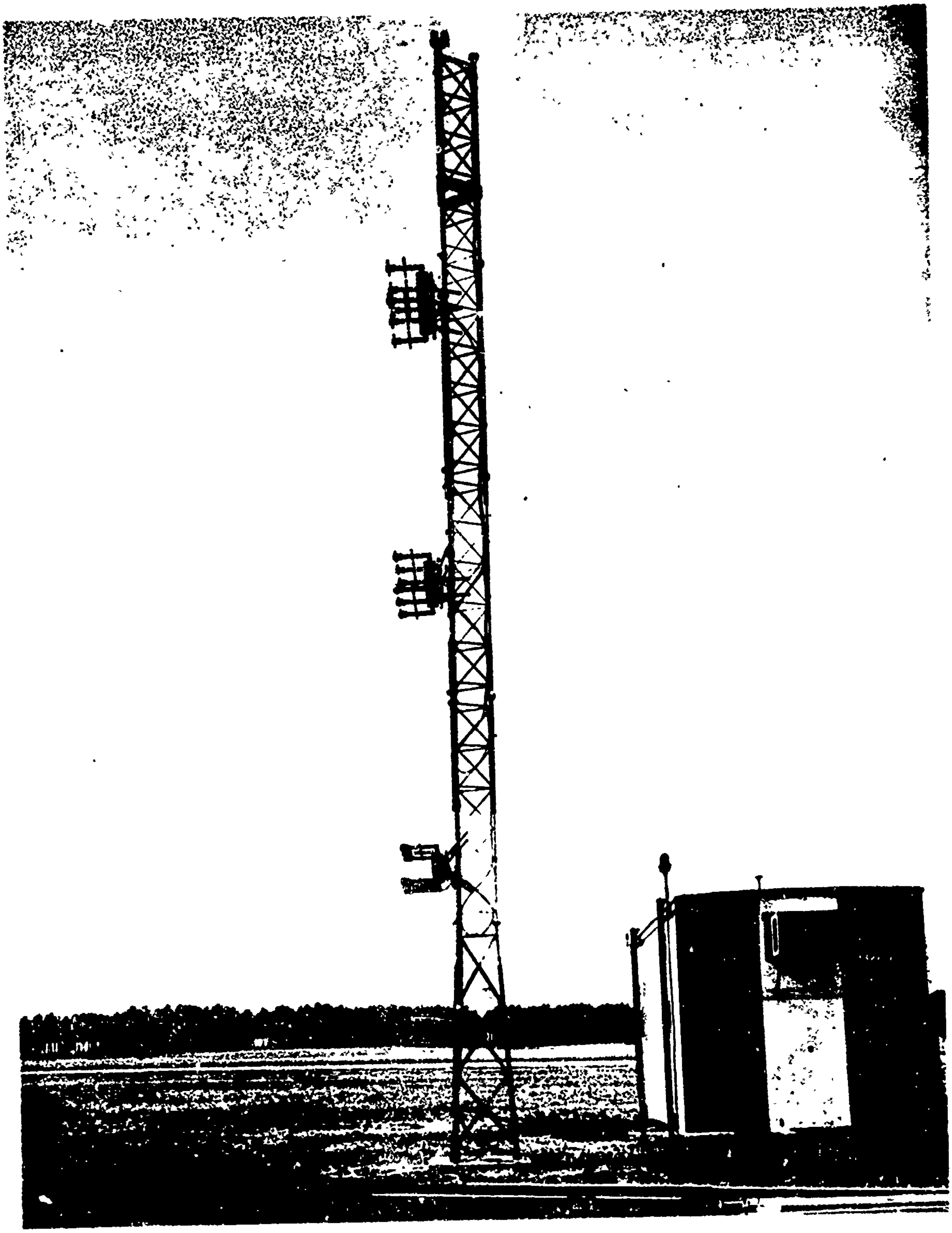

FIGURE 2 - STAN-38 TYPE-M ARRAY WITH PORTAKABIN VAN - SIDE VIEW

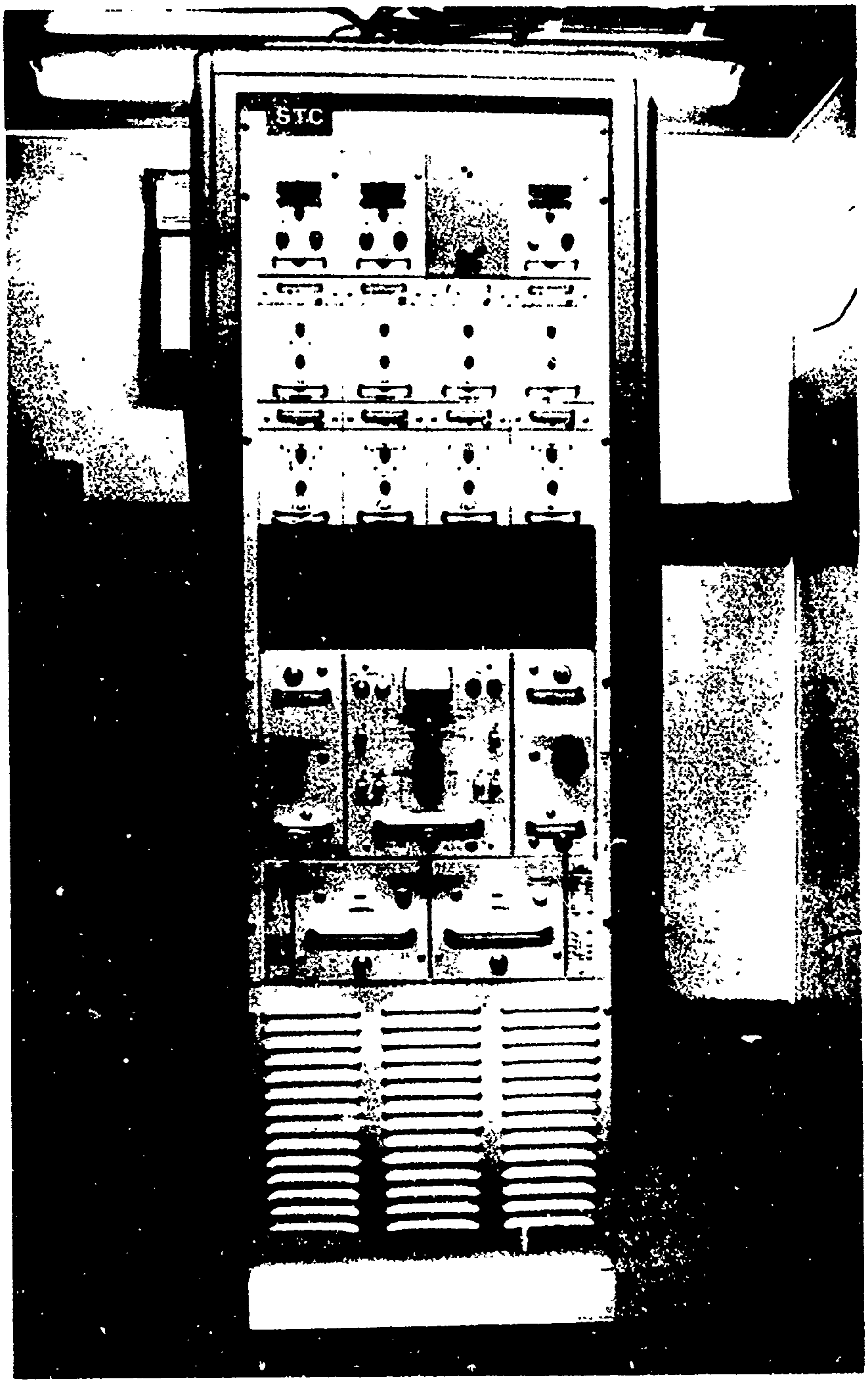

FIGURE 3 - STAN-38 GLIDE SLOPE EQUIPMENT CABINET

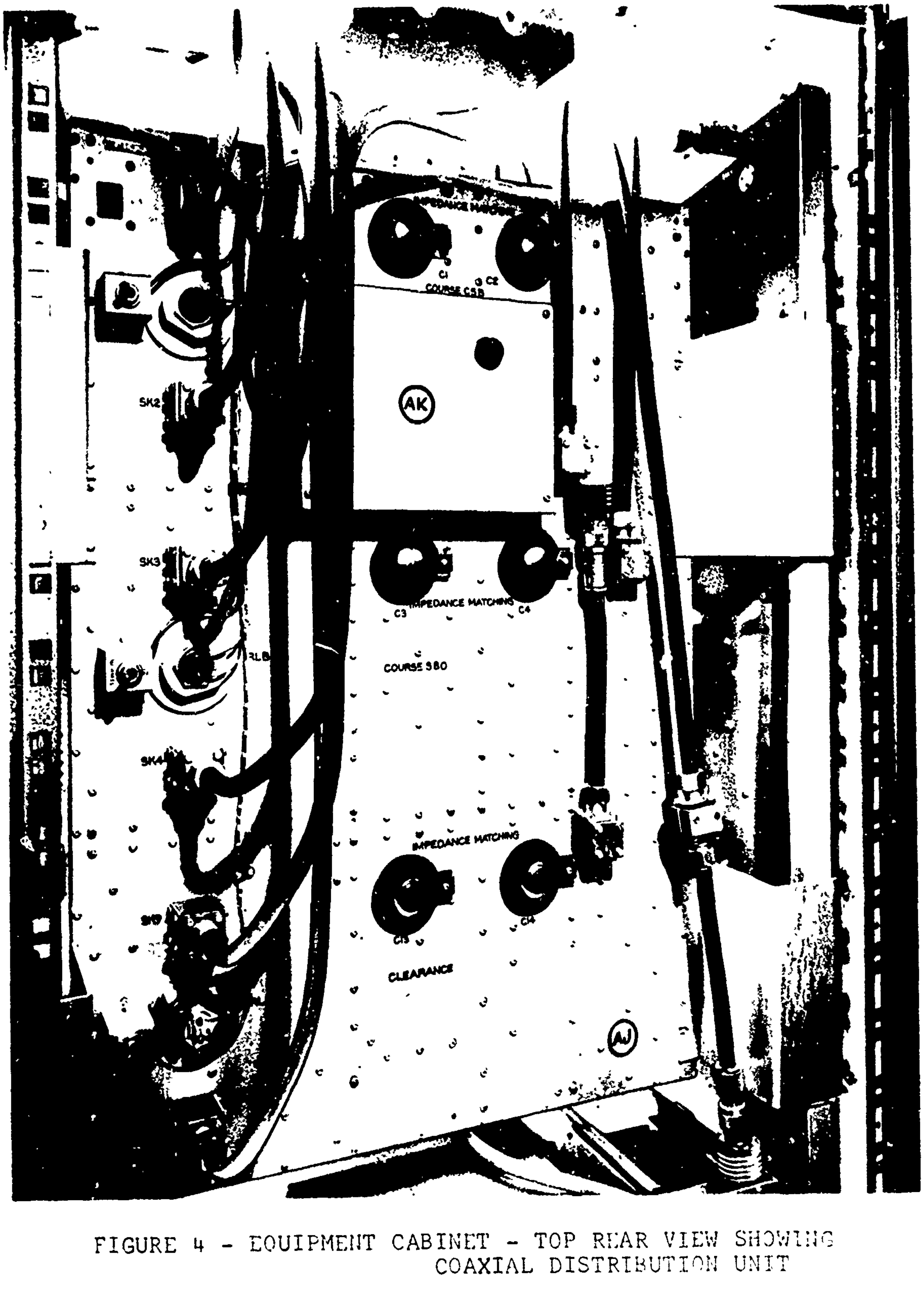

FIGURE 4 - EQUIPMENT CABINET - TOP REAR VIEW SHOWING COAXIAL DISTRIBUTION UNIT

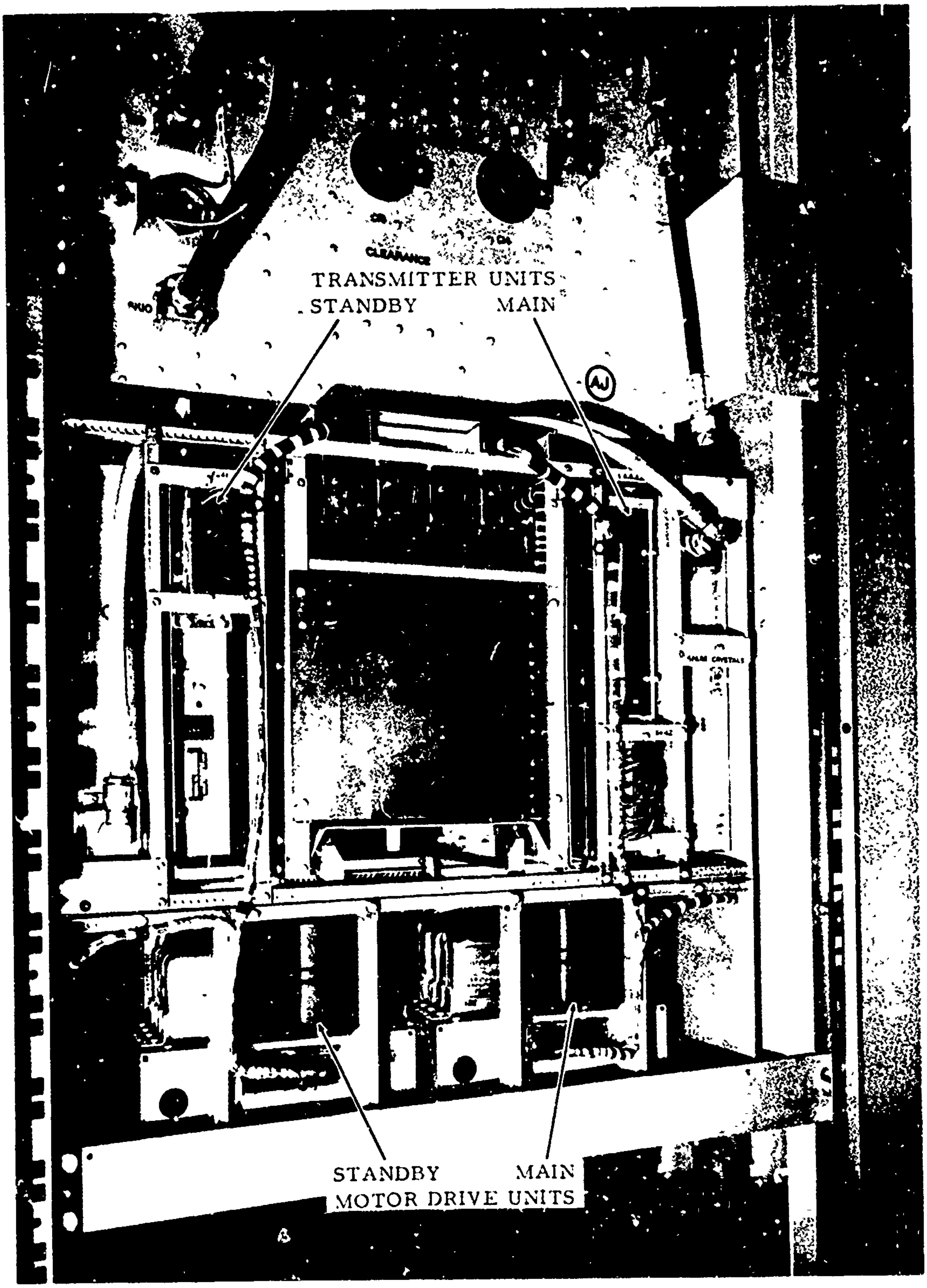

FIGURE 5 - EQUIPMENT CABINET - MID REAR VIEW

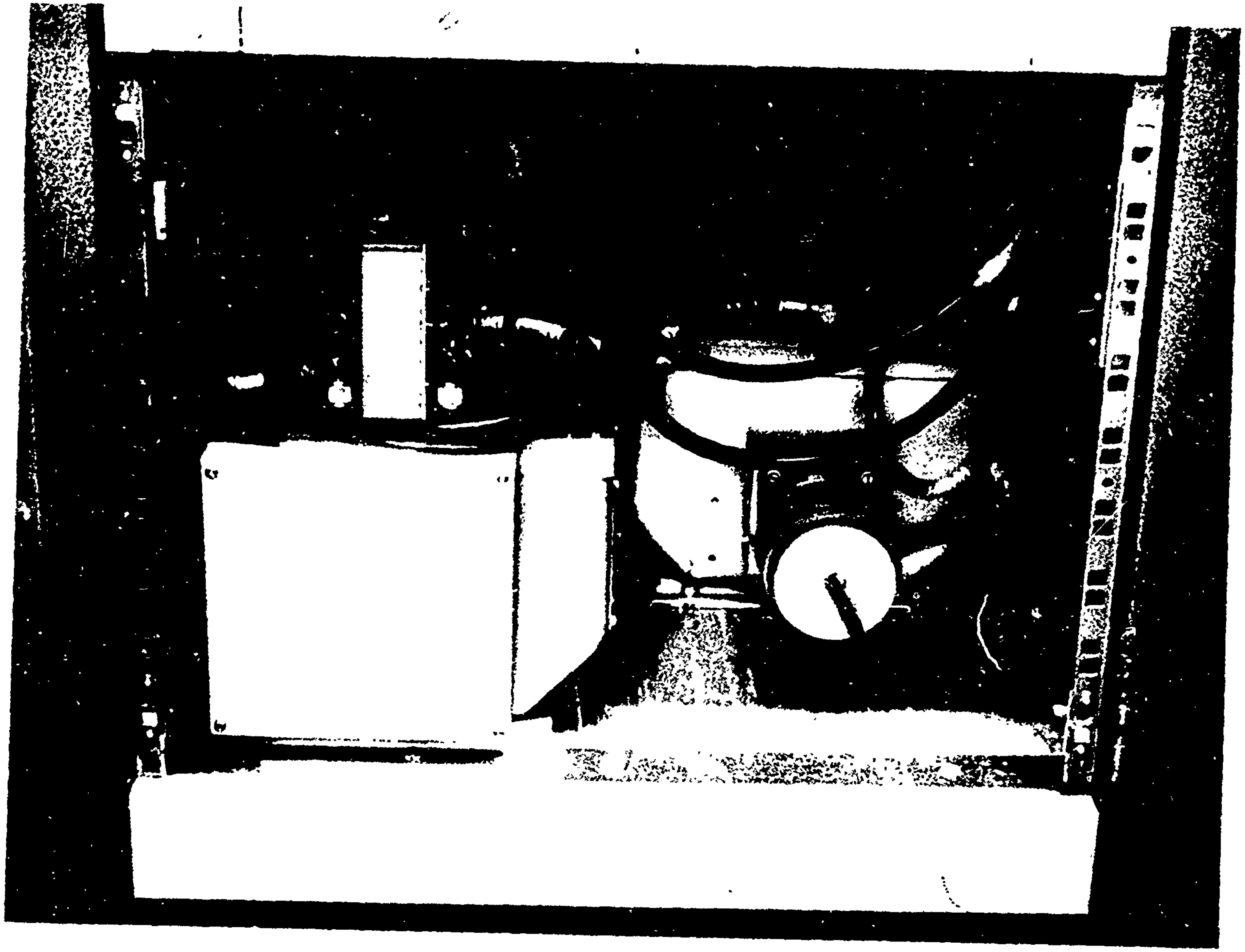

FIGURE 6 - EQUIPMENT CABINET - BOTTOM REAR VIEW SHOWING MECHANICAL MODULATORS

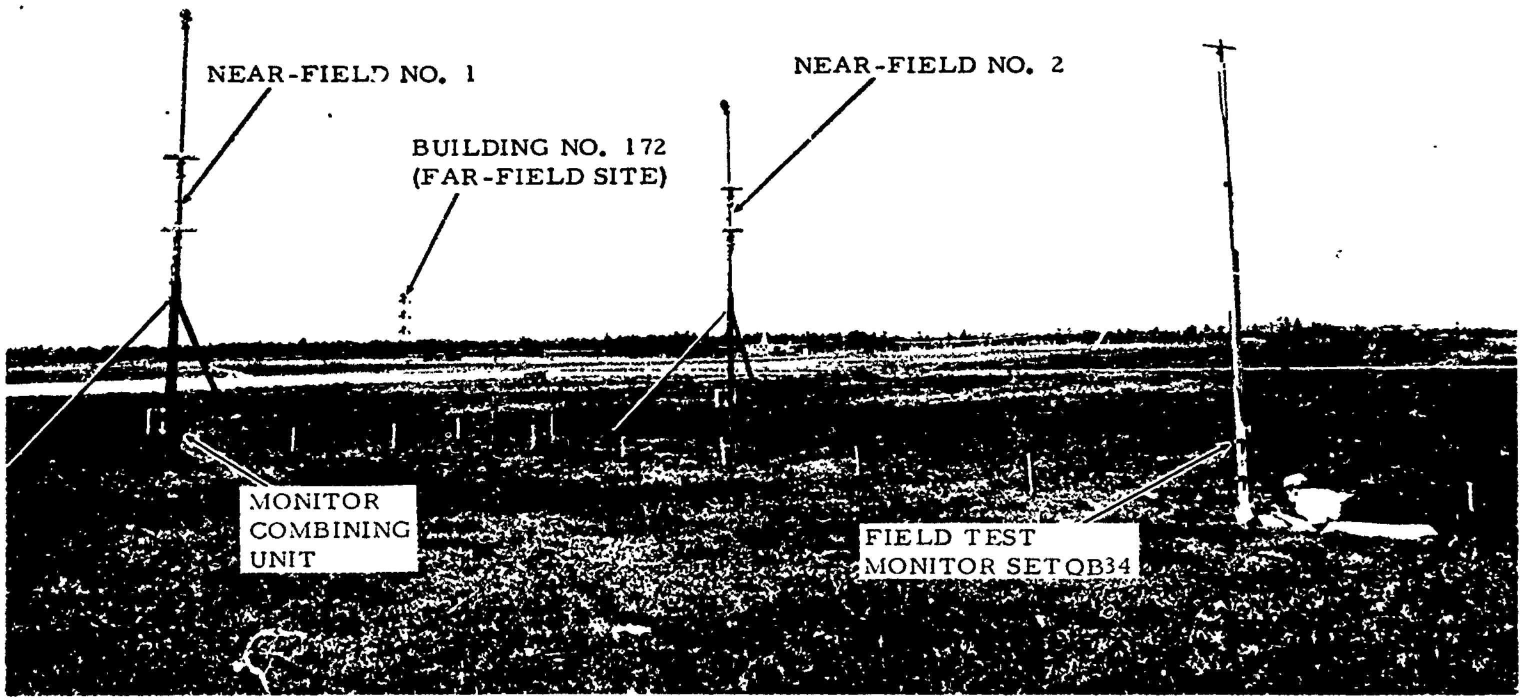

FIGURE 7 - STAN-38 MONITOR INSTALLATION AND QB34 FIELD SETUP

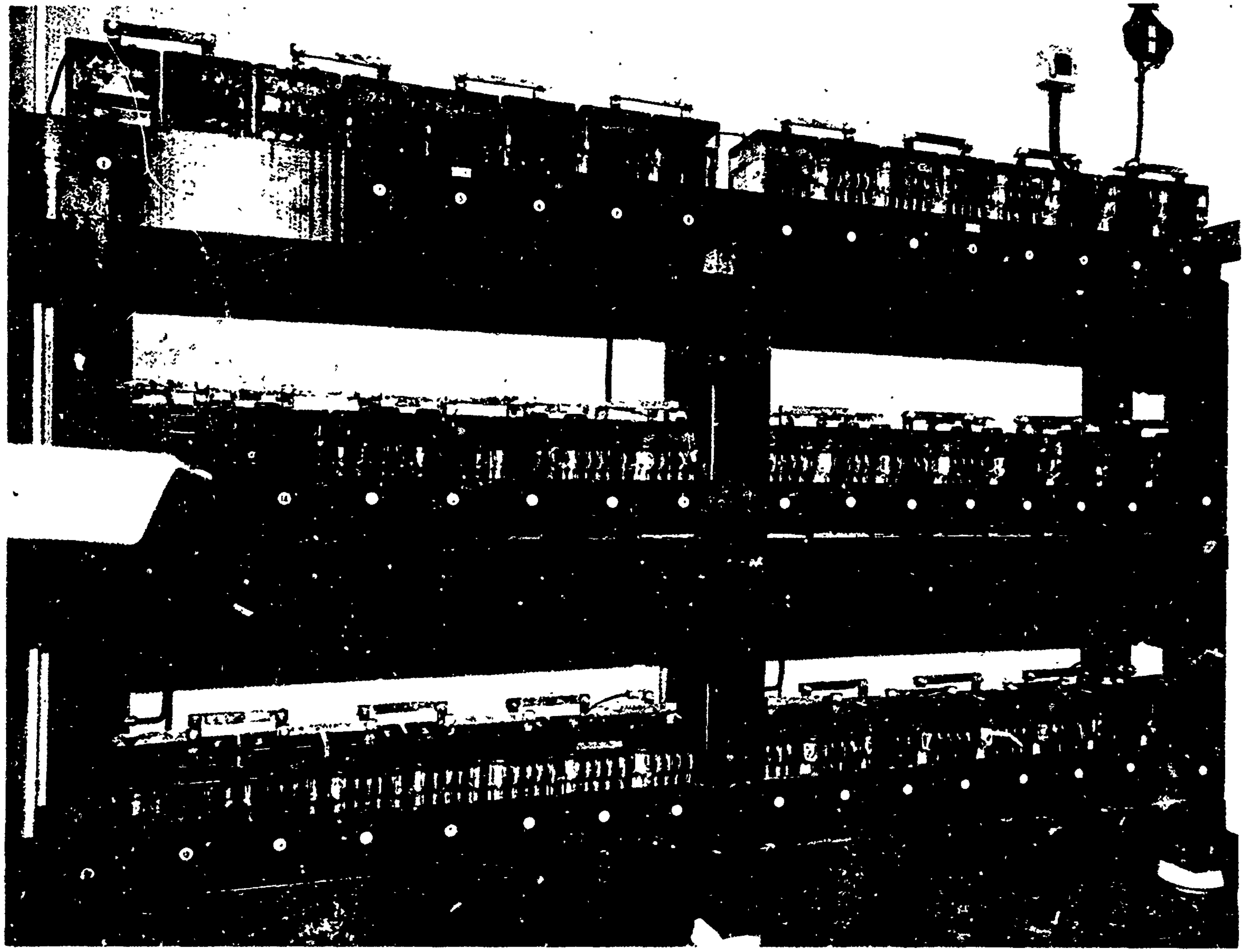

FIGURE 8 - TRANSMITTER BATTERY BANKS (48V)

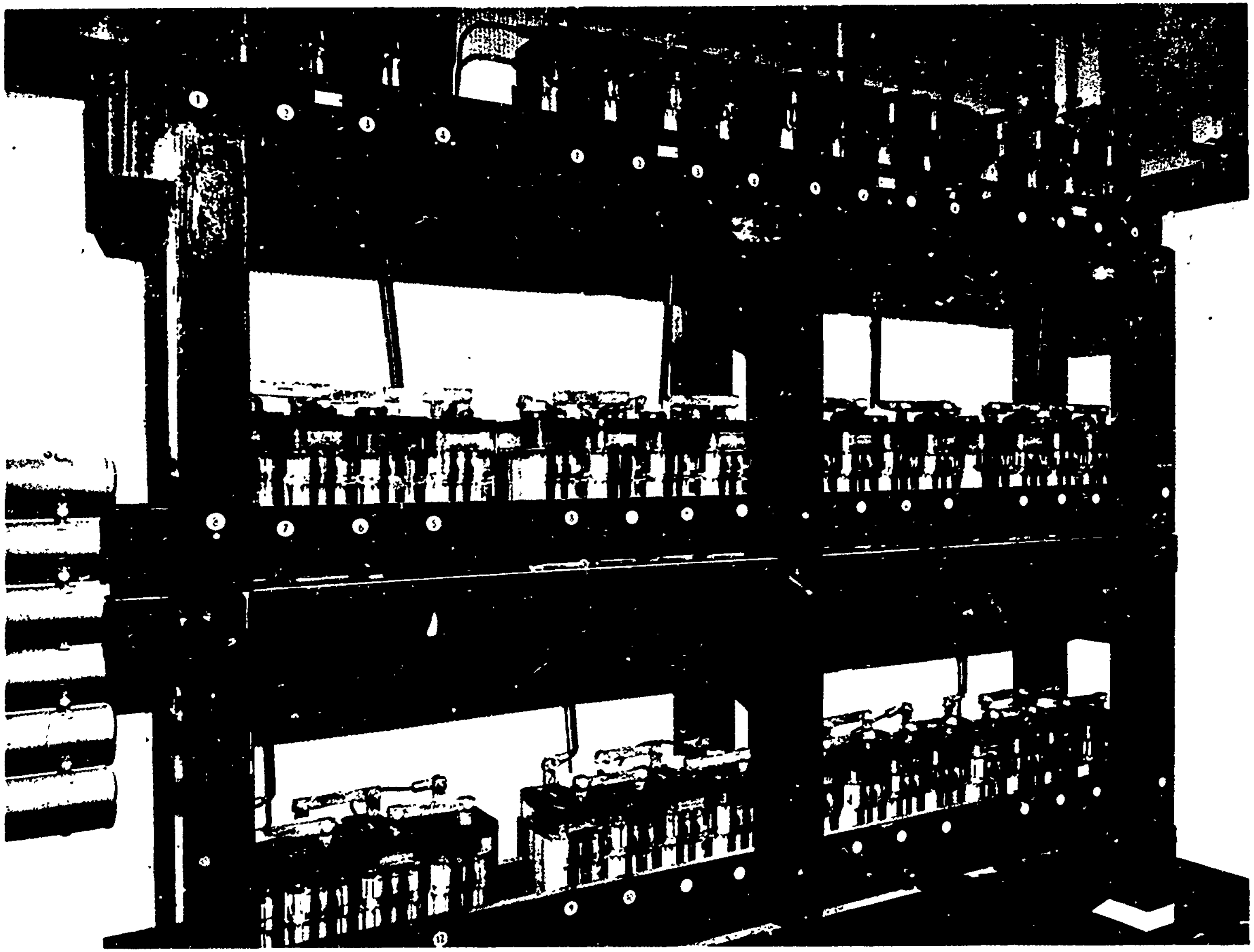

FIGURE 9 - MONITOR BATTERY BANKS (24V)

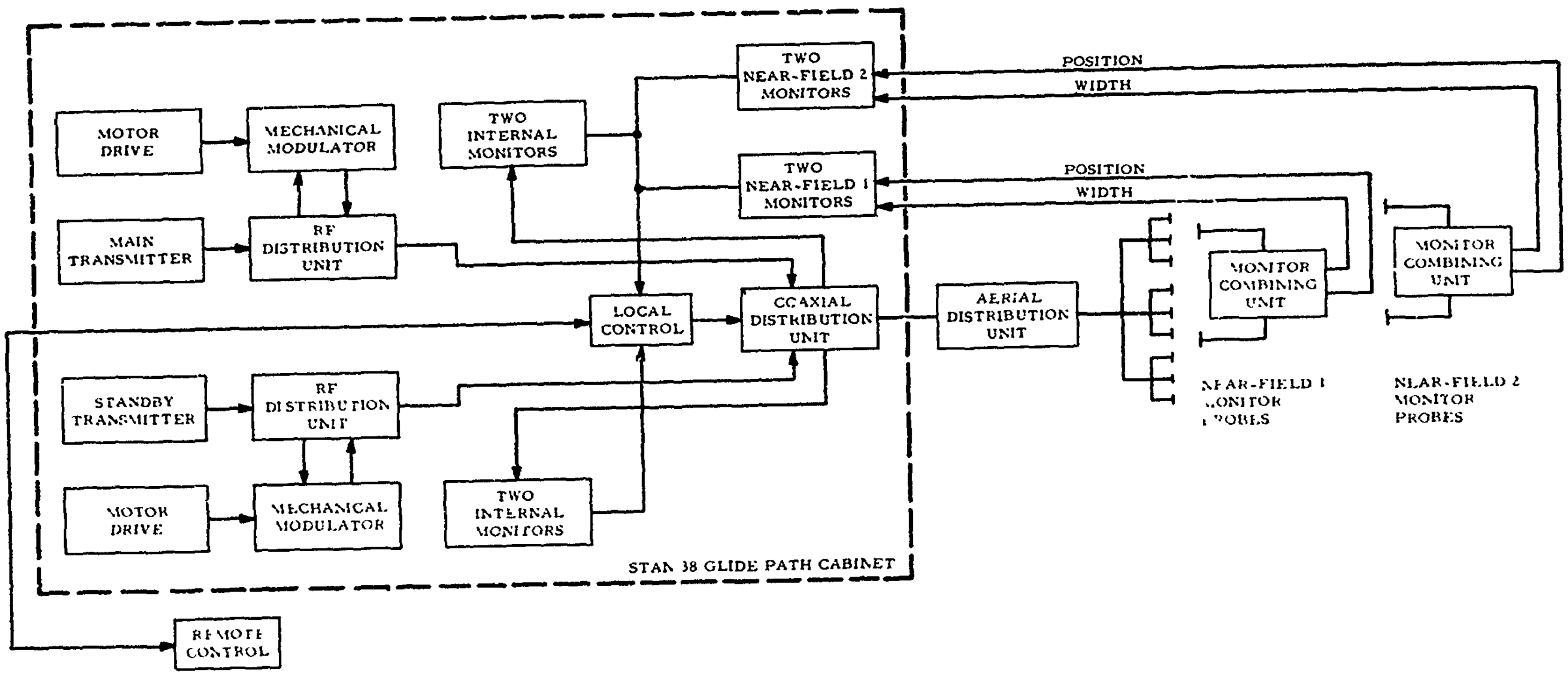

FIGURE 10 - STAN-38 TYPE-M SYSTEM BLOCK DIAGRAM

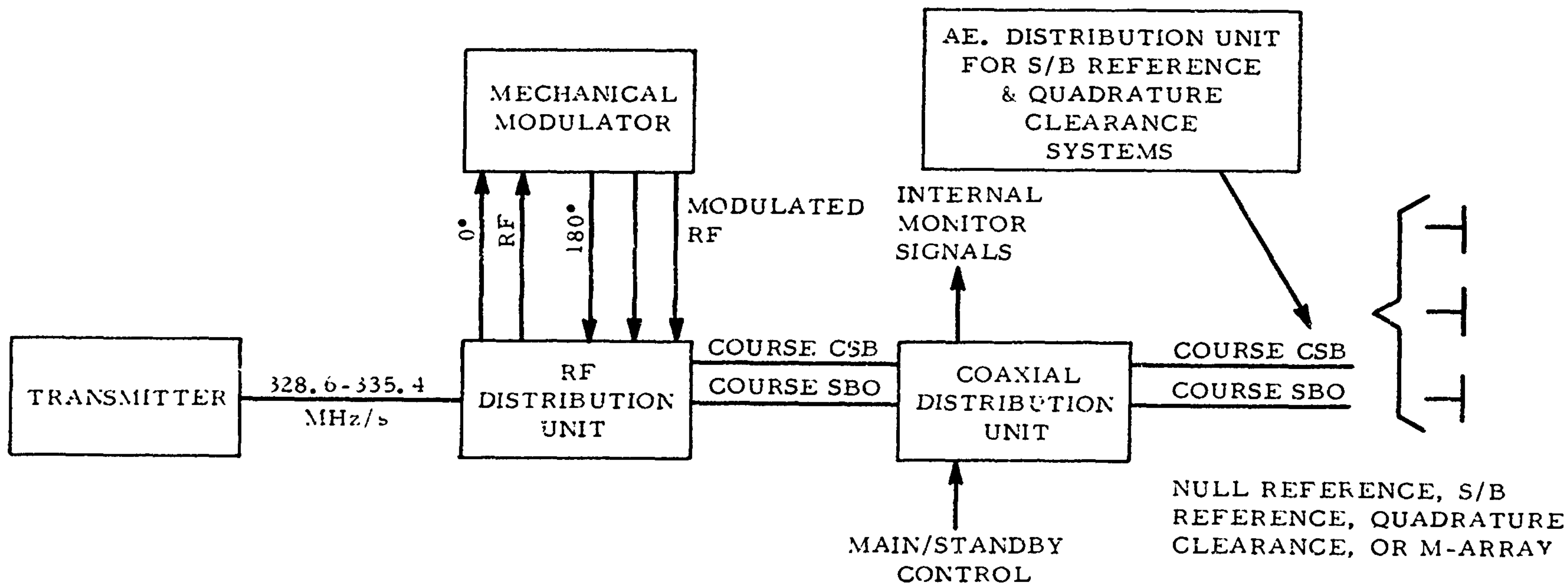

FIGURE 11 - RF GENERATION AND DISTRIBUTION

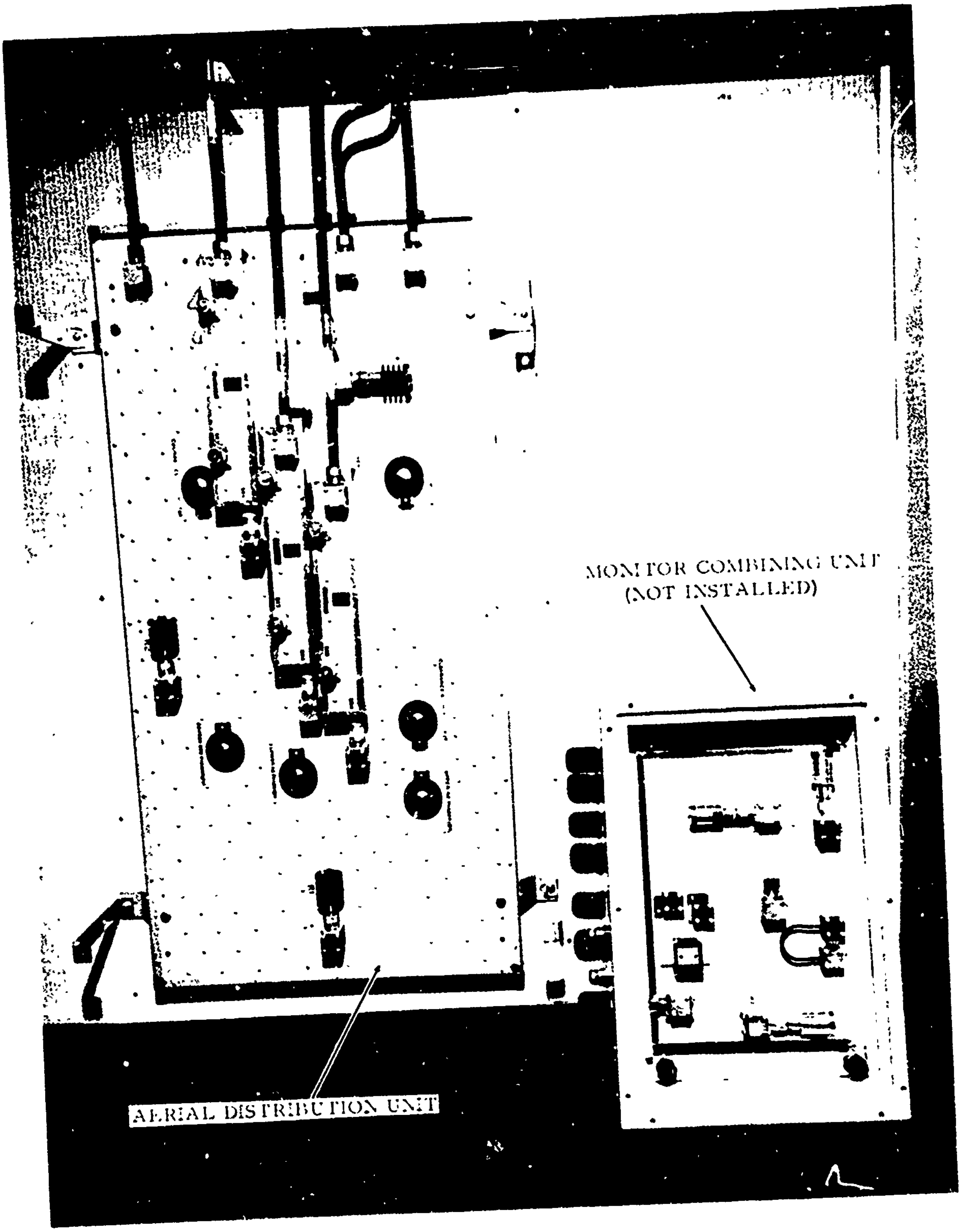

FIGURE 12 - AERIAL DISTRIBUTION UNIT AND MONITOR COMBINING UNIT

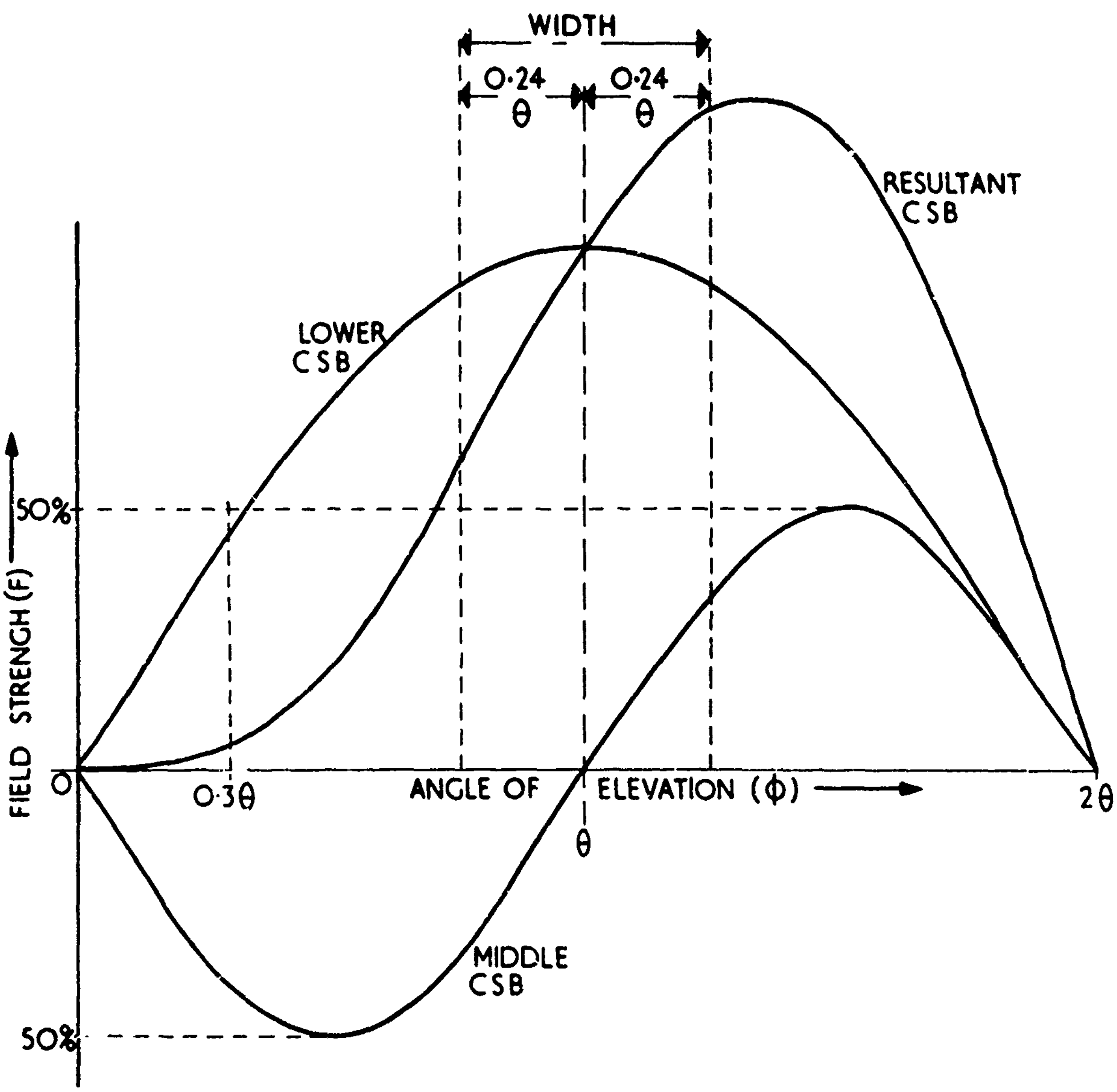

FIGURE 13 - COURSE CSB RADIATION PATTERN

SOURCE - TELECOMMUNICATIONS TECHNICAL HANDBOOK

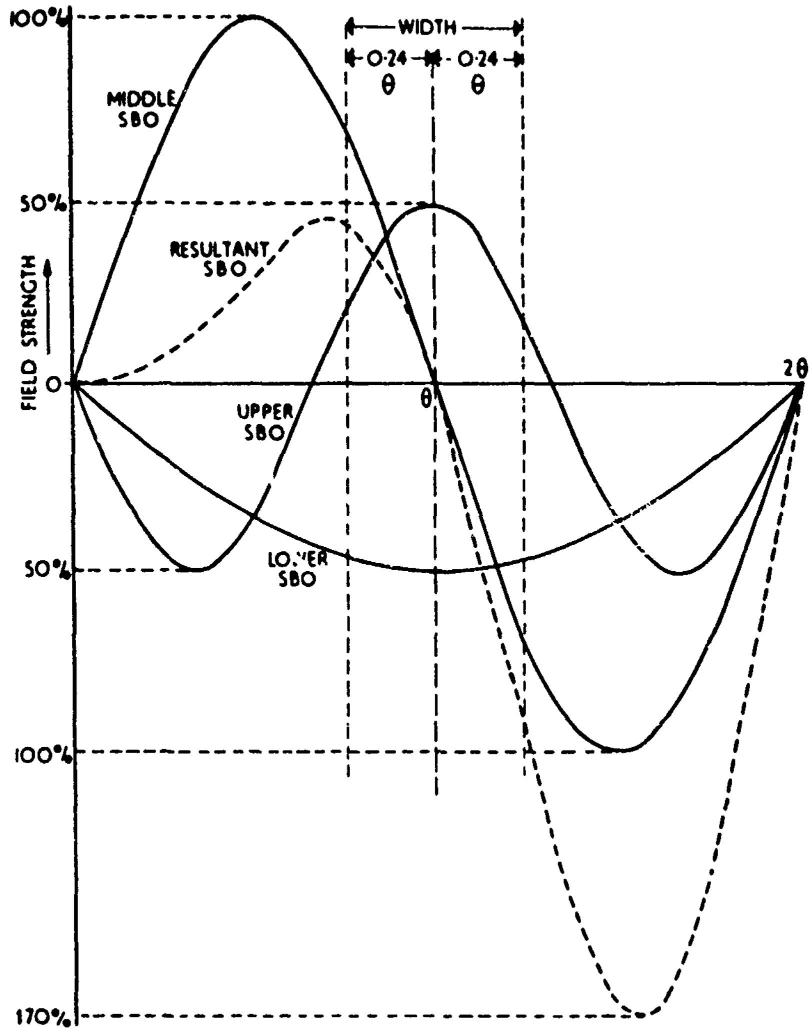

FIGURE 14 - COURSE SBO RADIATION PATTERN

SOURCE - TELECOMMUNICATIONS TECHNICAL HANDBOOK

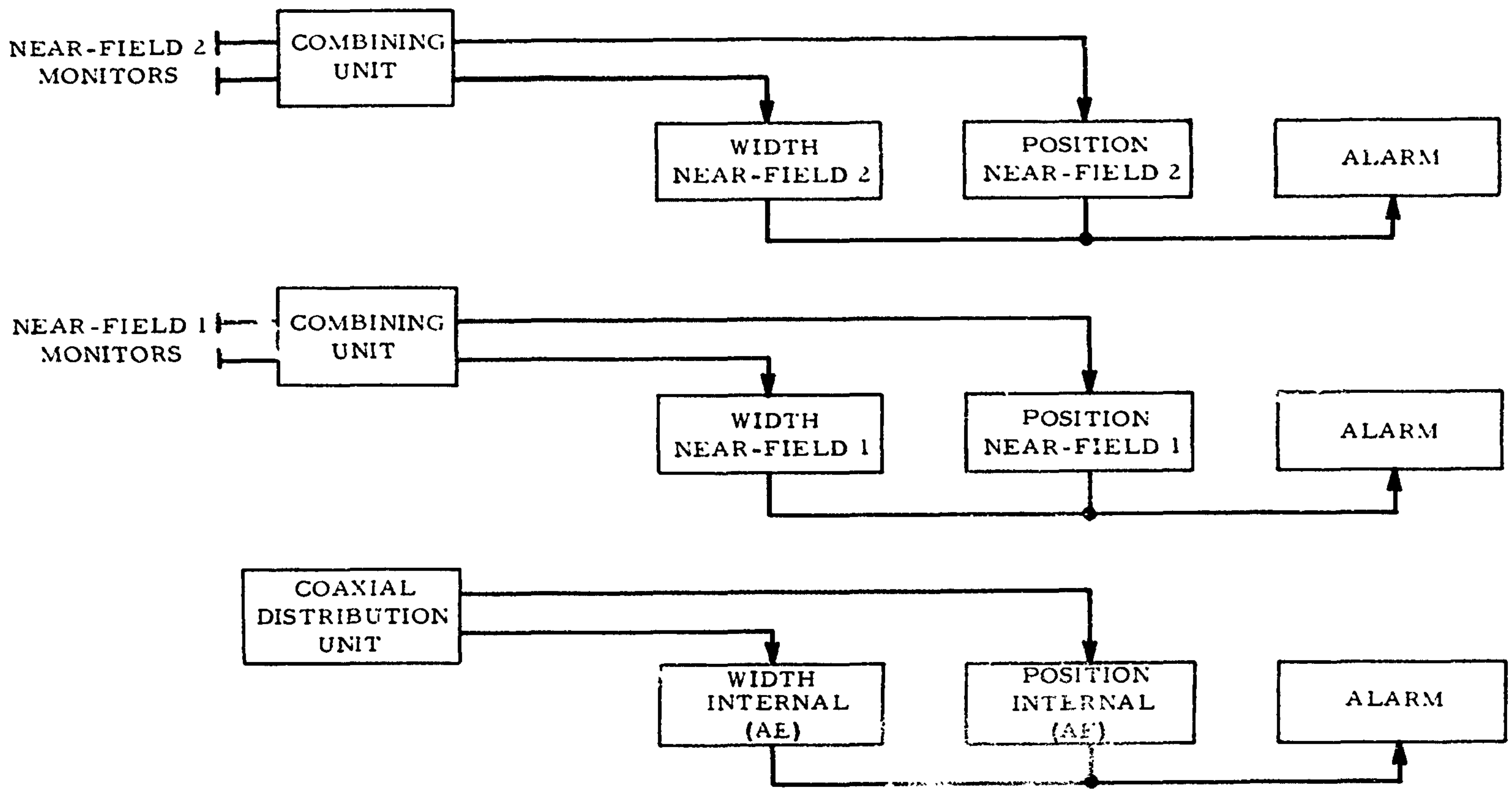

FIGURE 15 - MAIN EQUIPMENT MONITOR CONFIGURATION

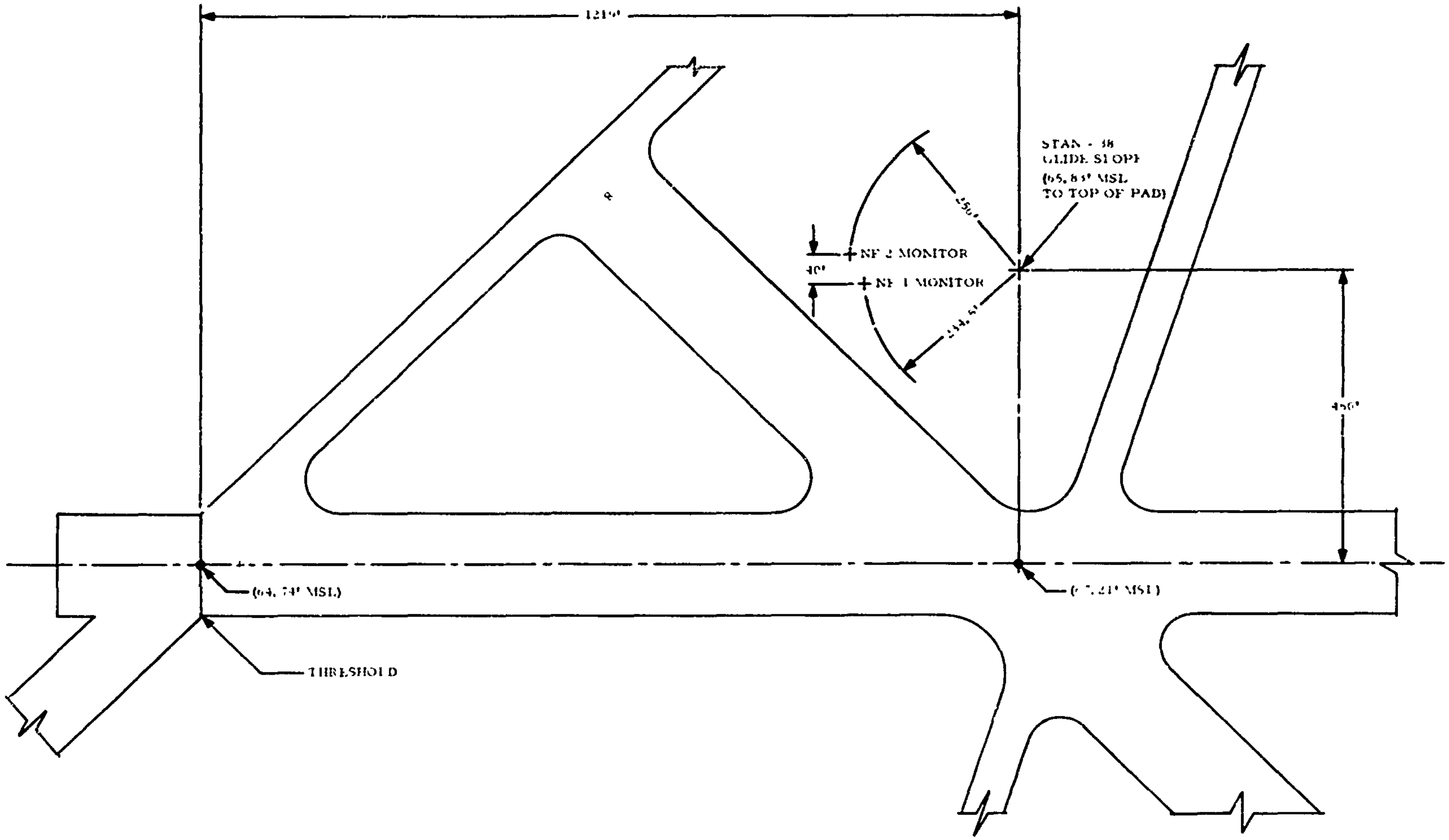

FIGURE 16 - STAN-38 GLIDE SLOPE SITE LAYOUT

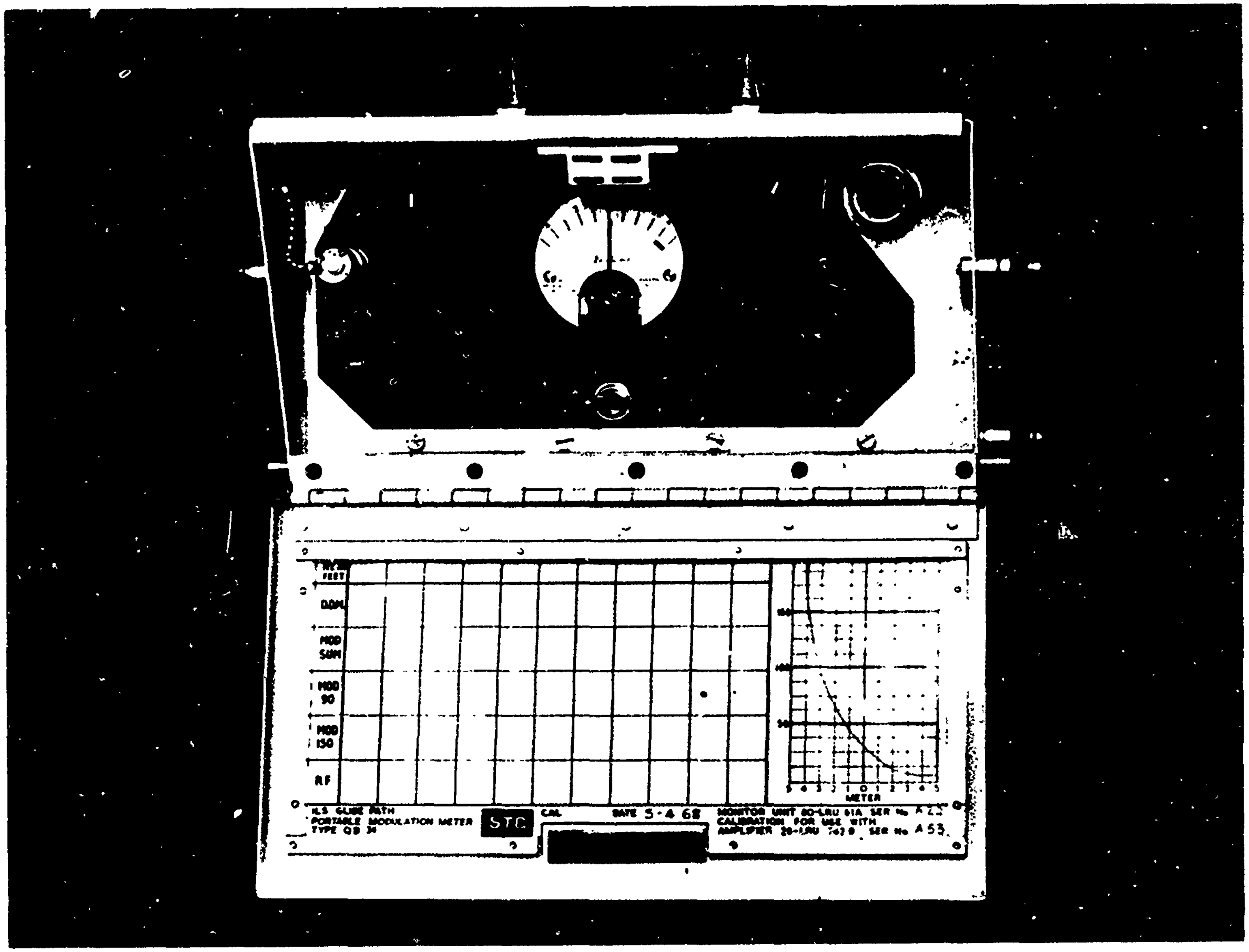

FIGURE 17 - FIELD TEST MONITOR SET QB34

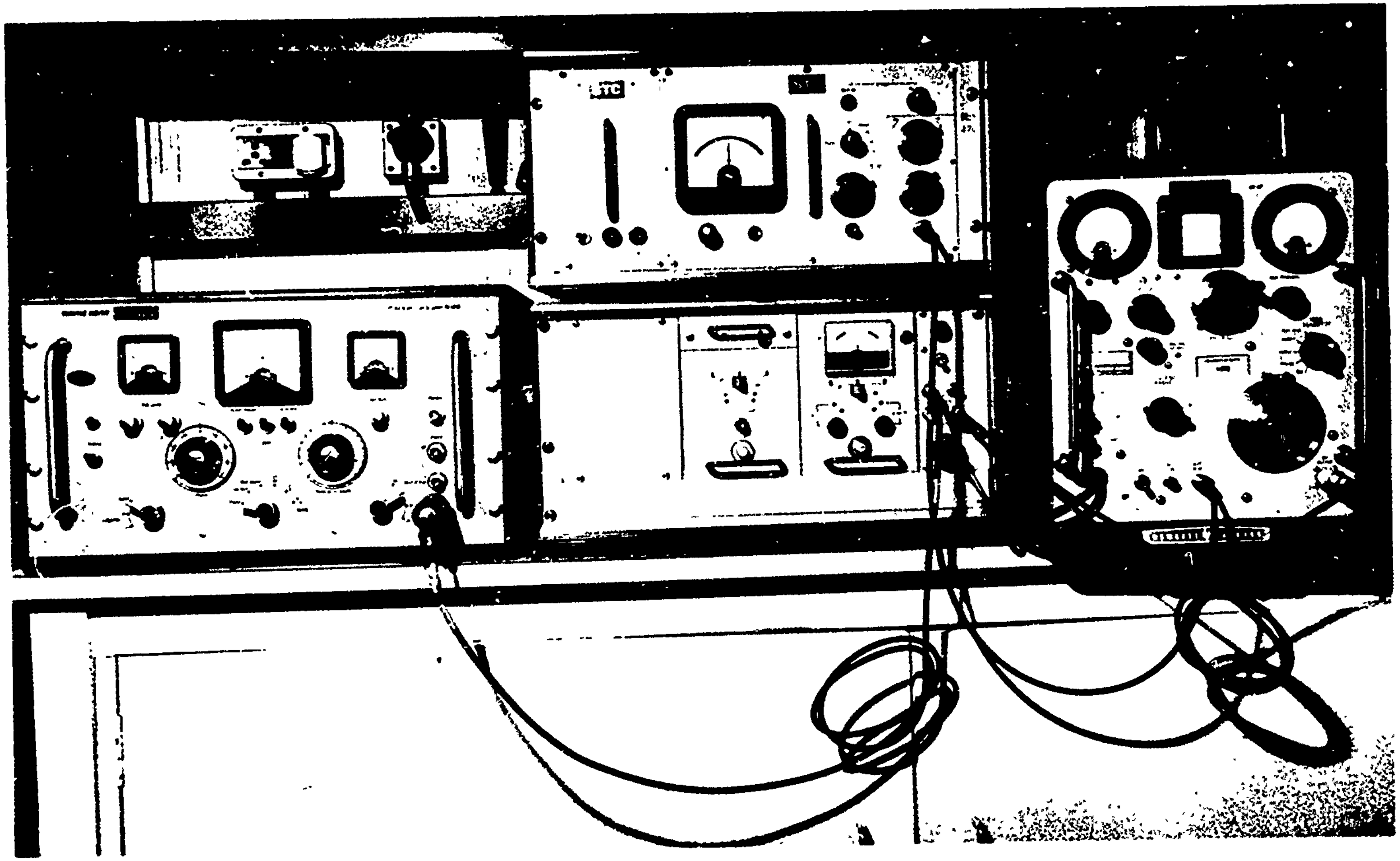

FIGURE 18 - BENCH SETUP FOR MONITOR UNIT CALIBRATION

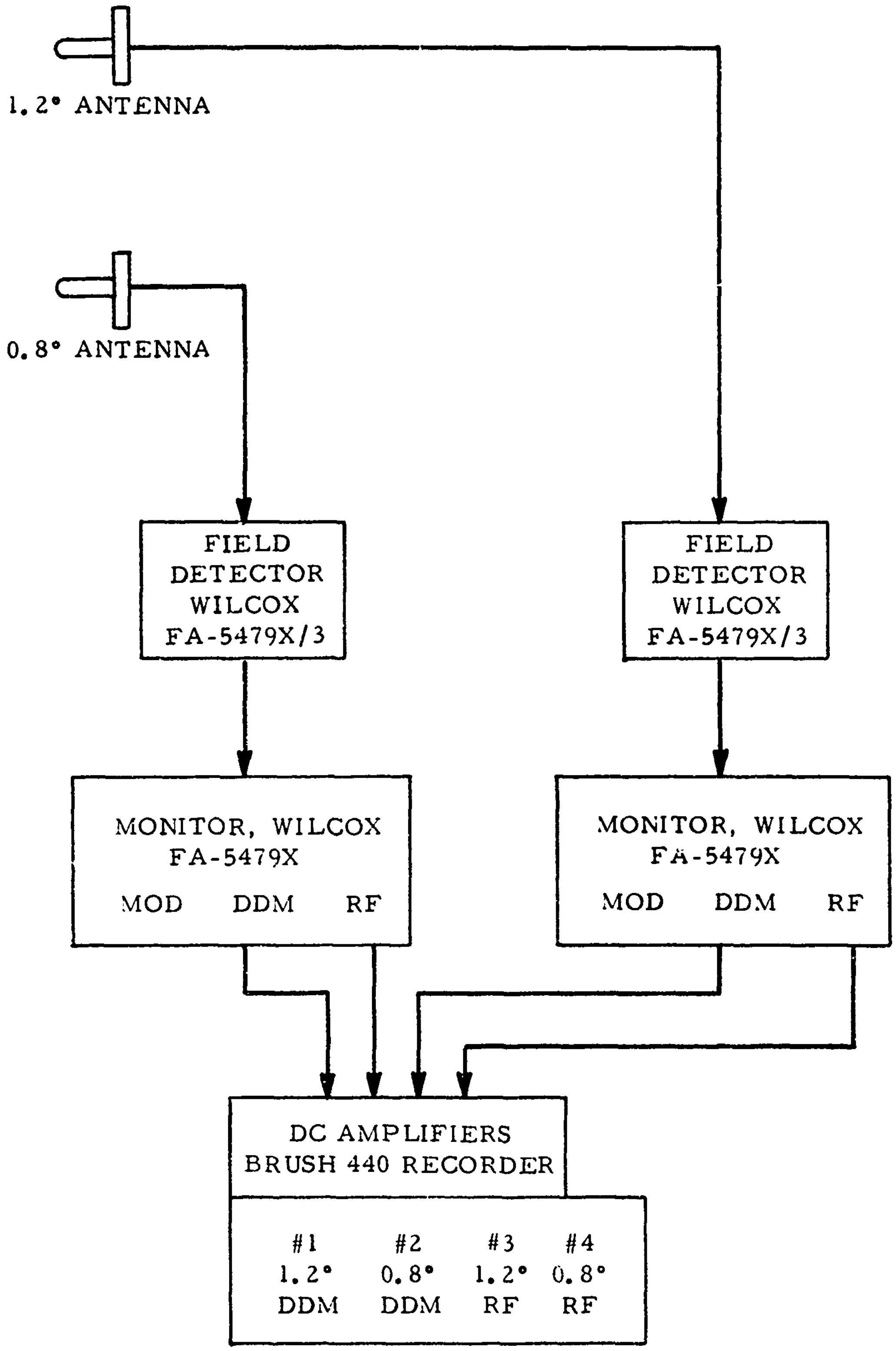

FIGURE 13 - FAP-FIELD EQUIPMENT SETUP

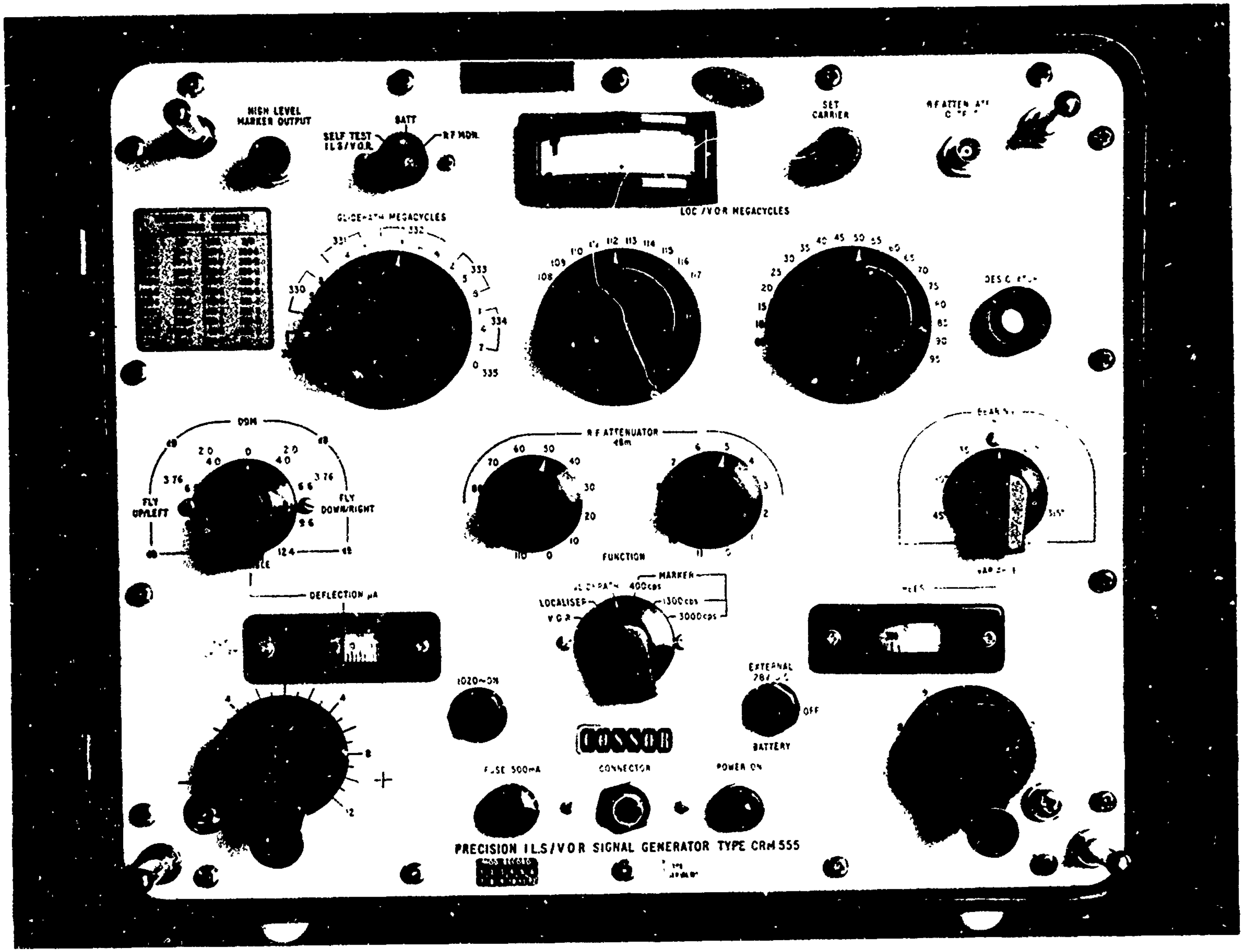

FIGURE 20 - ILS TEST SET, CRM-555

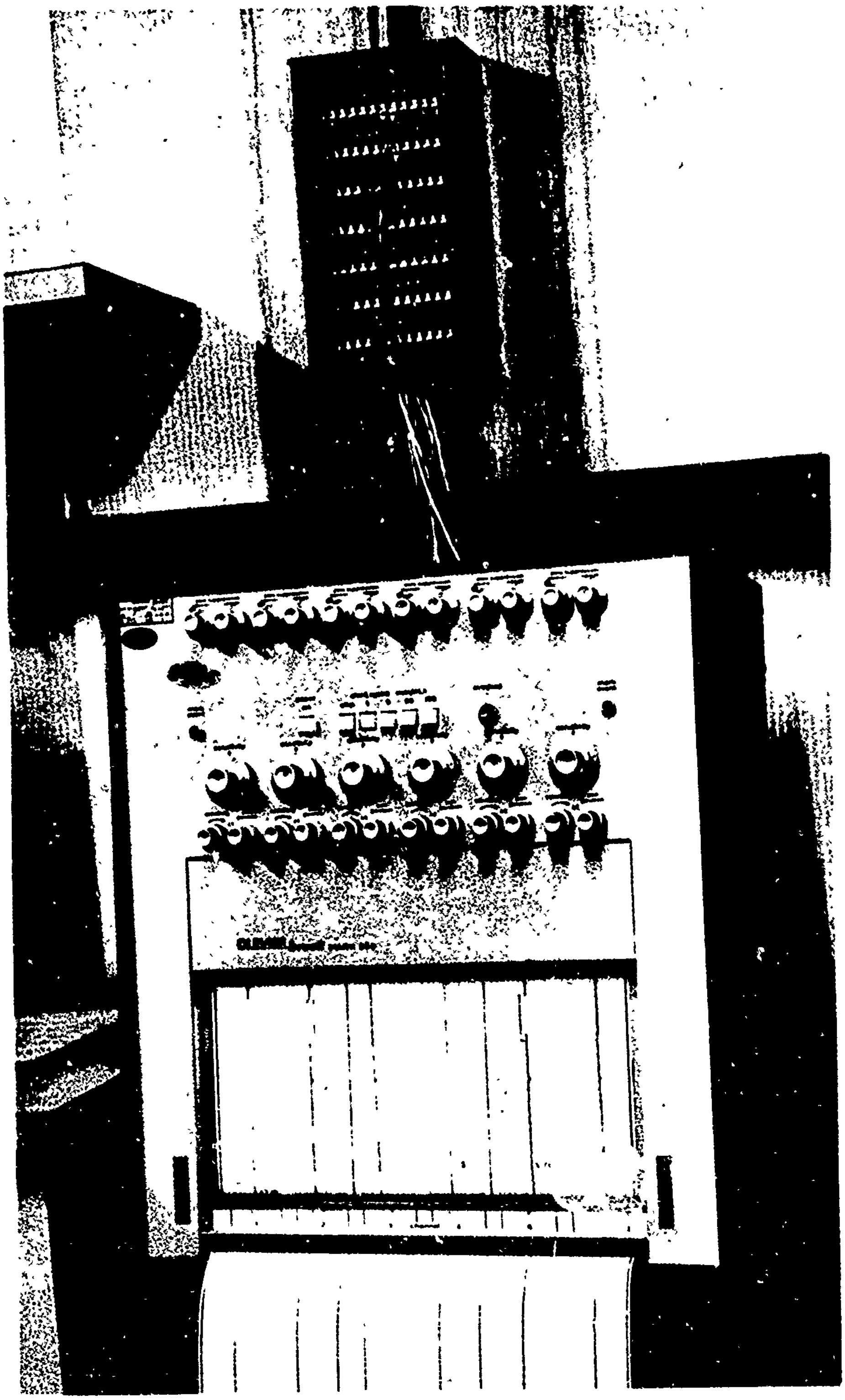

FIGURE 21 - PORTAKABIN INSTRUMENTATION

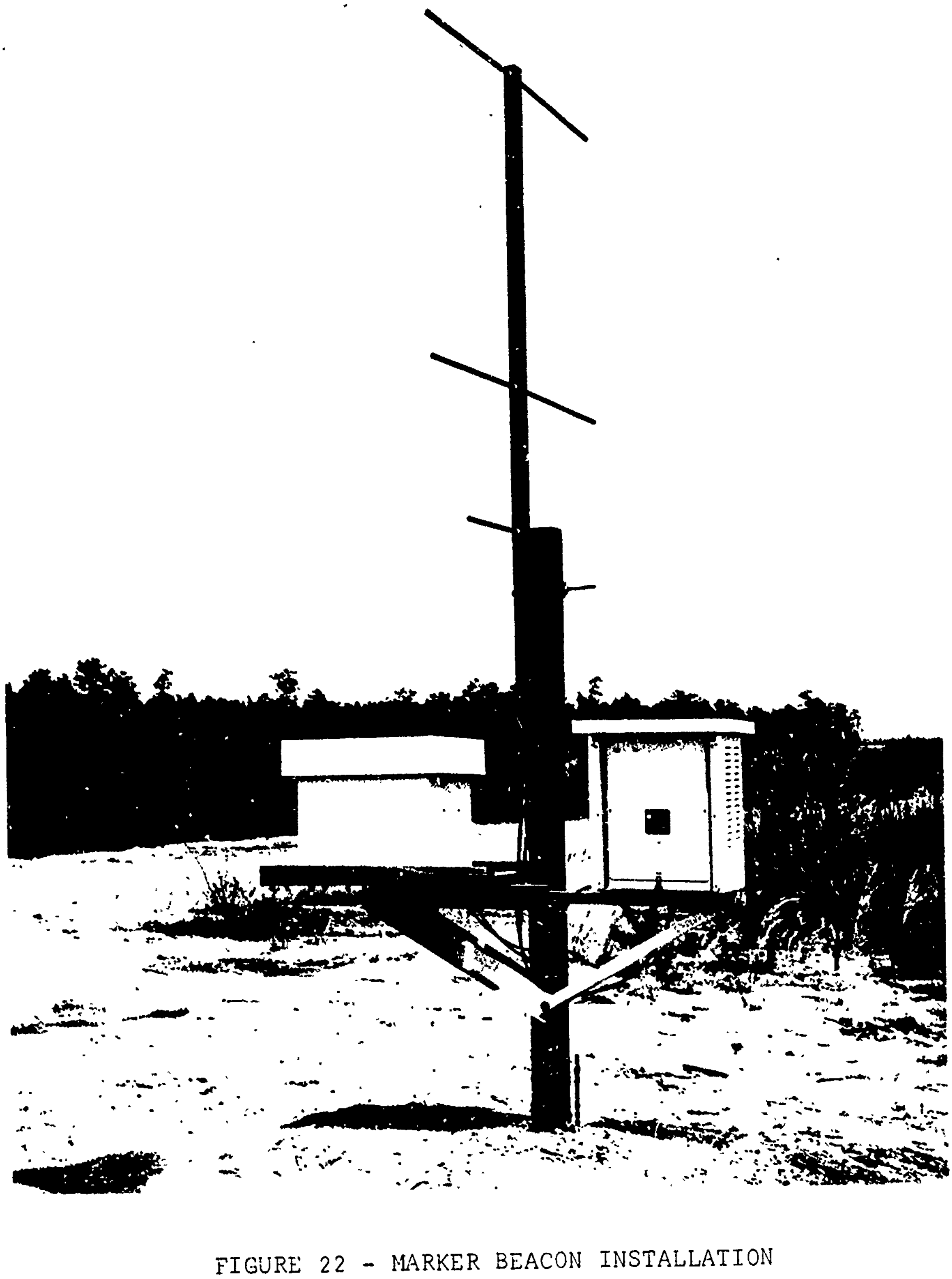

FIGURE 22 - MARKER BEACON INSTALLATION

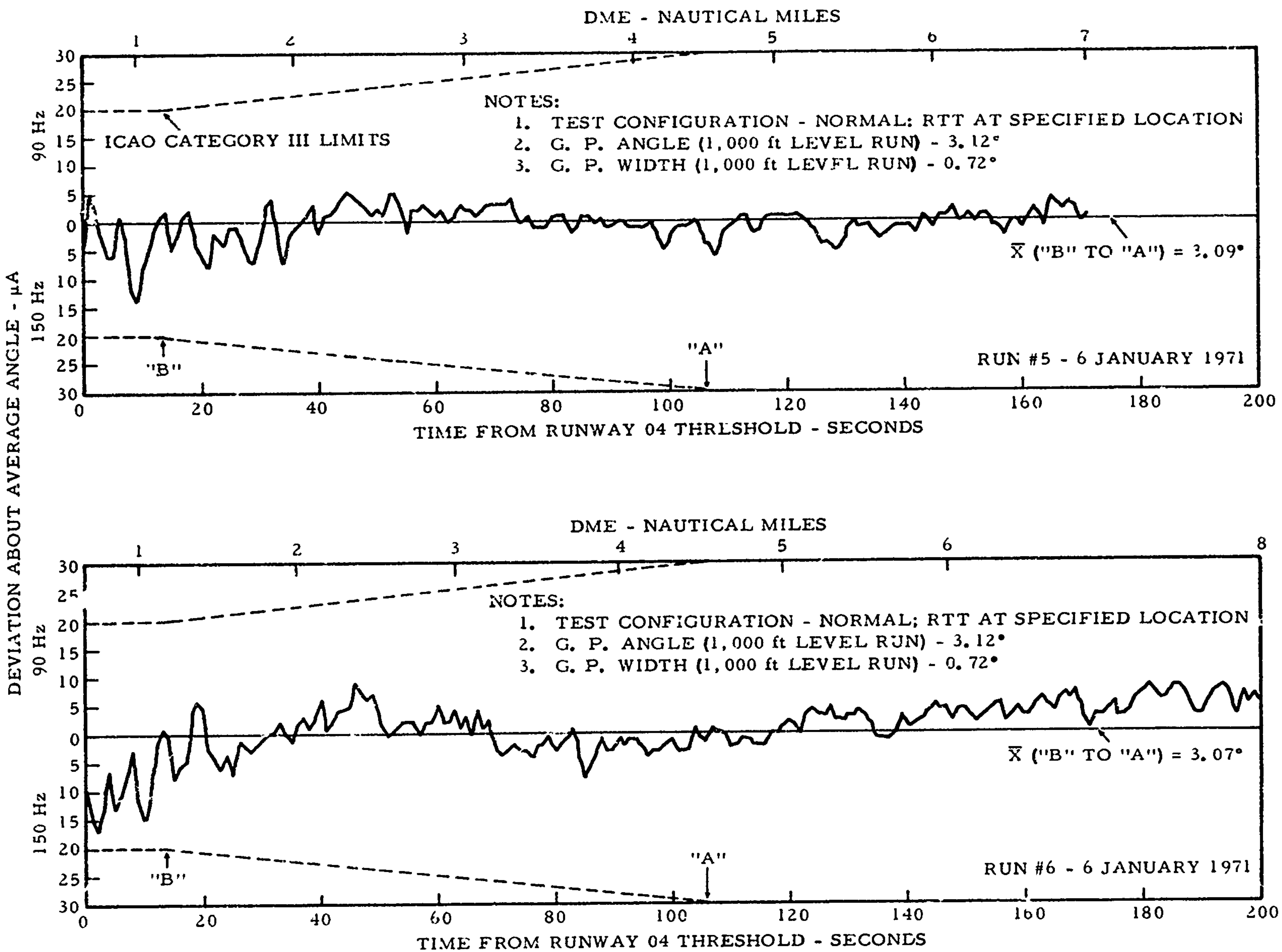

FIGURE 23 - STAN-38 GLIDE-PATH STRUCTURES

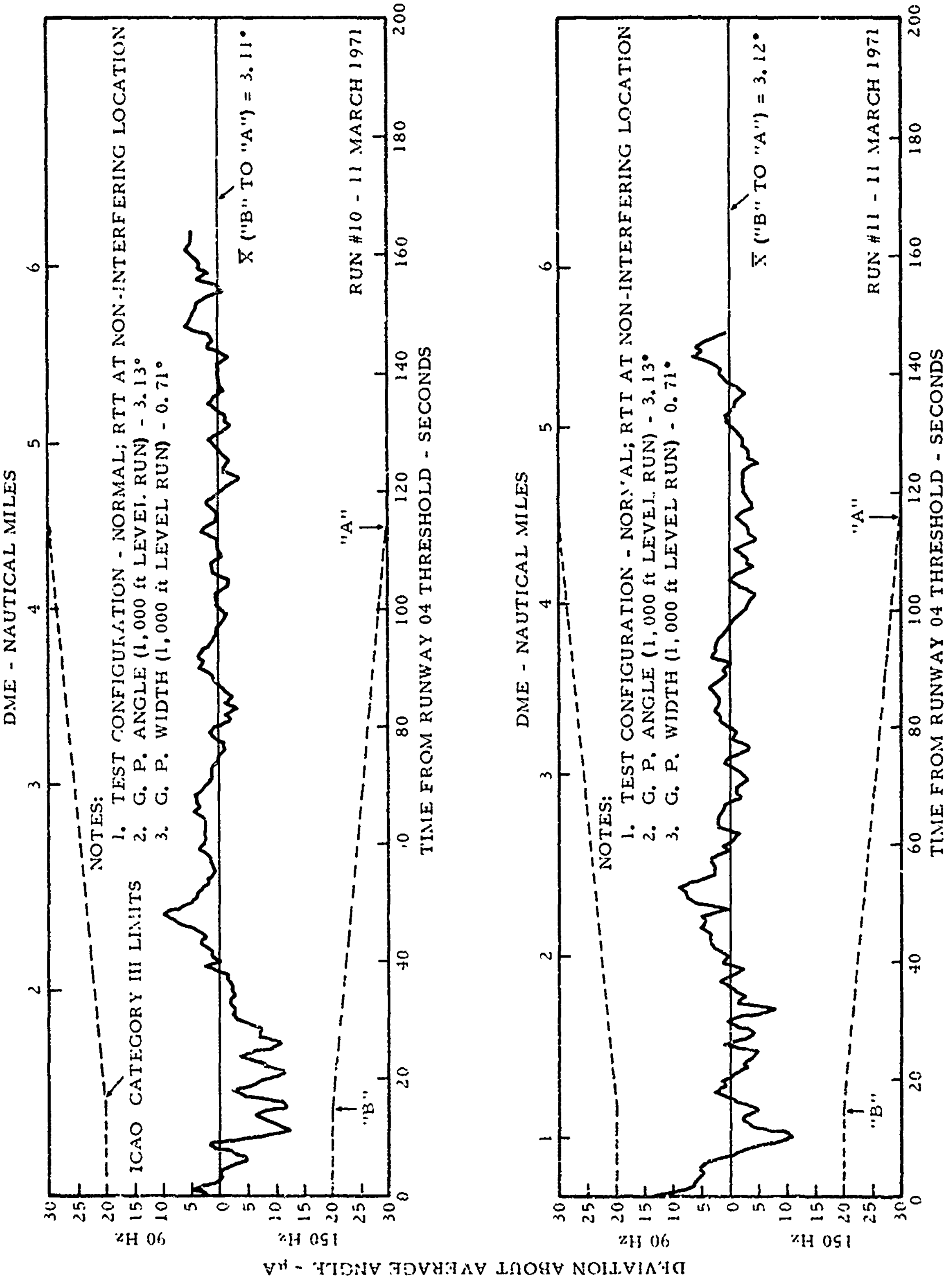

FIGURE 24 - STAN-38 GLIDE-PATH STRUCTURES

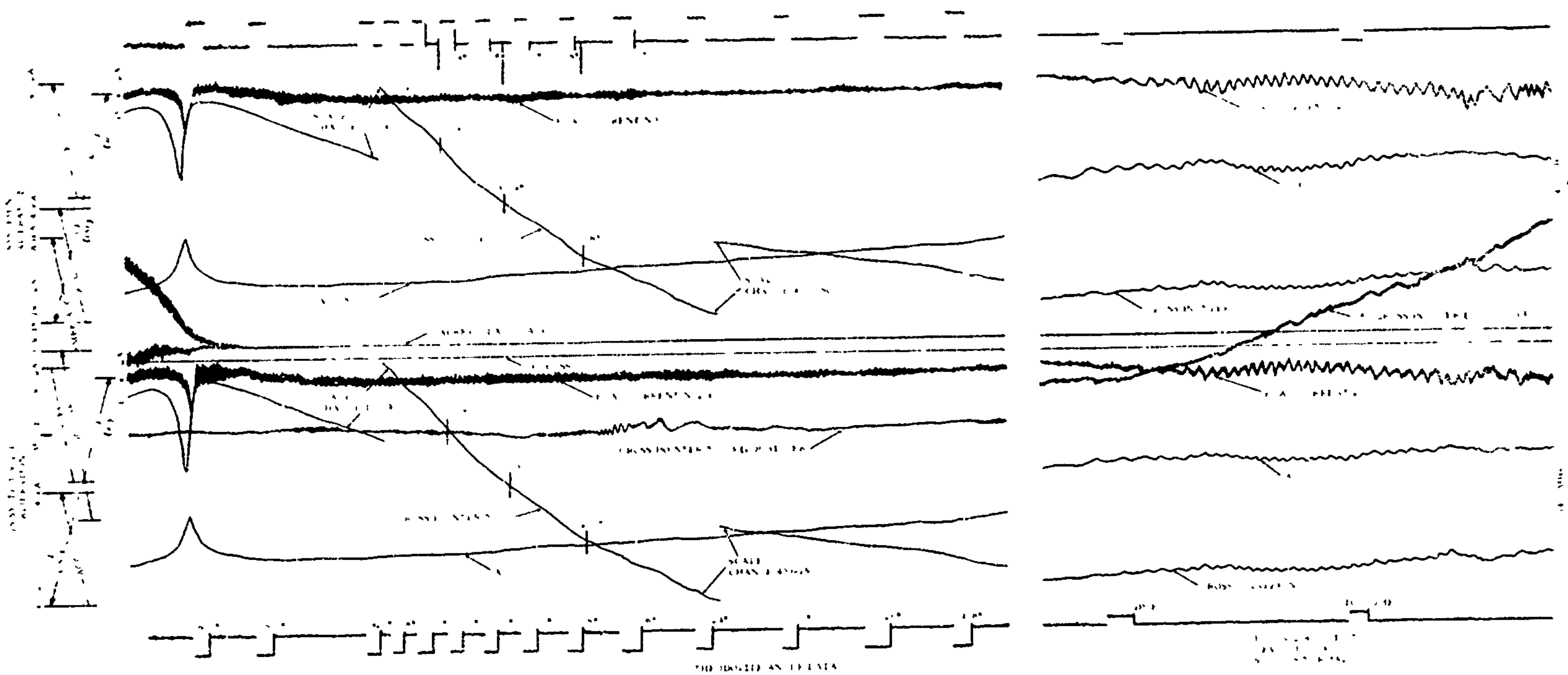

FIGURE 25 - AIRBORNE RECORDING - PATH WIDTH AND CLEARANCE

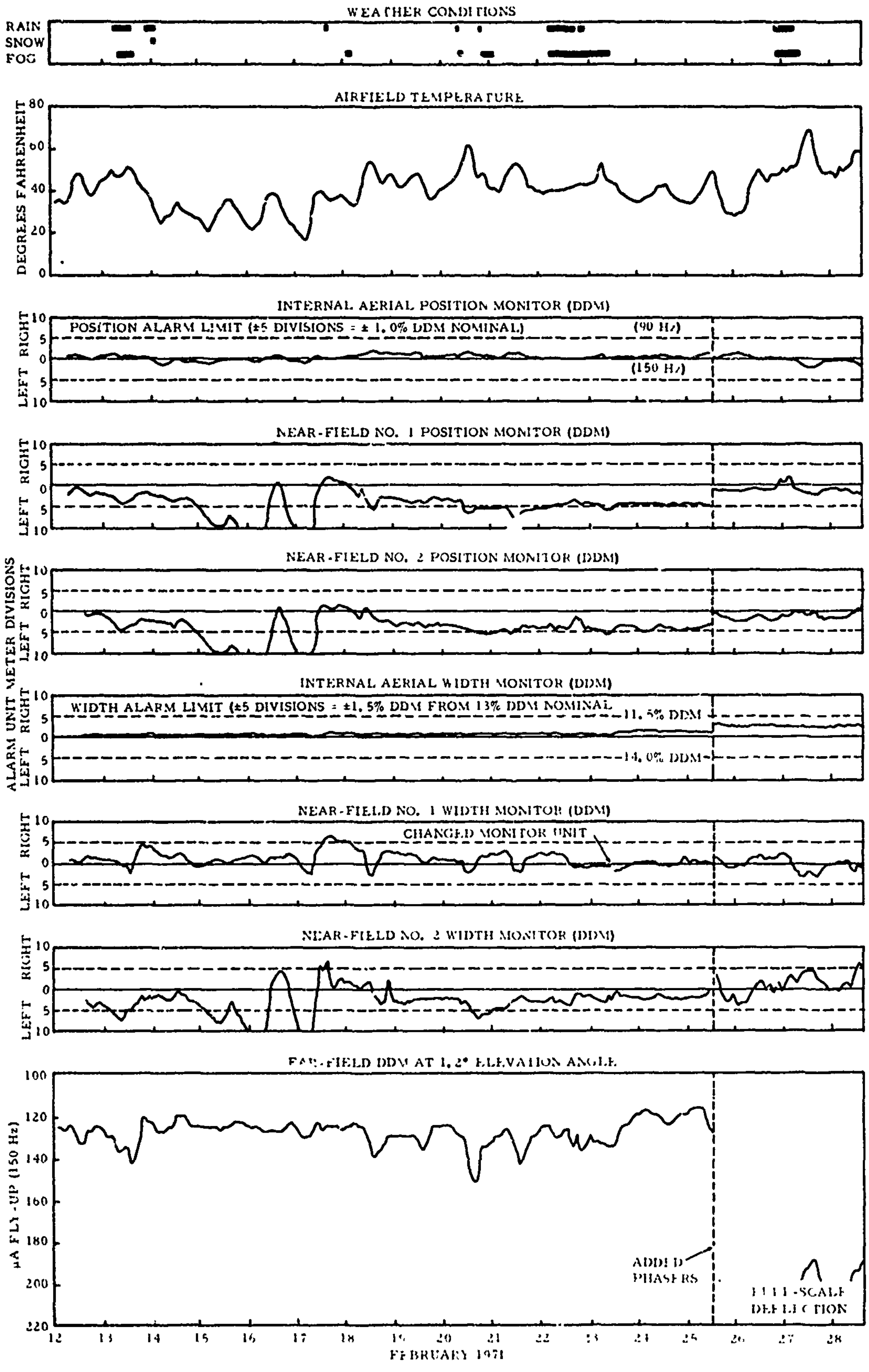

FIGURE 26. MONITOR - WEATHER DATA

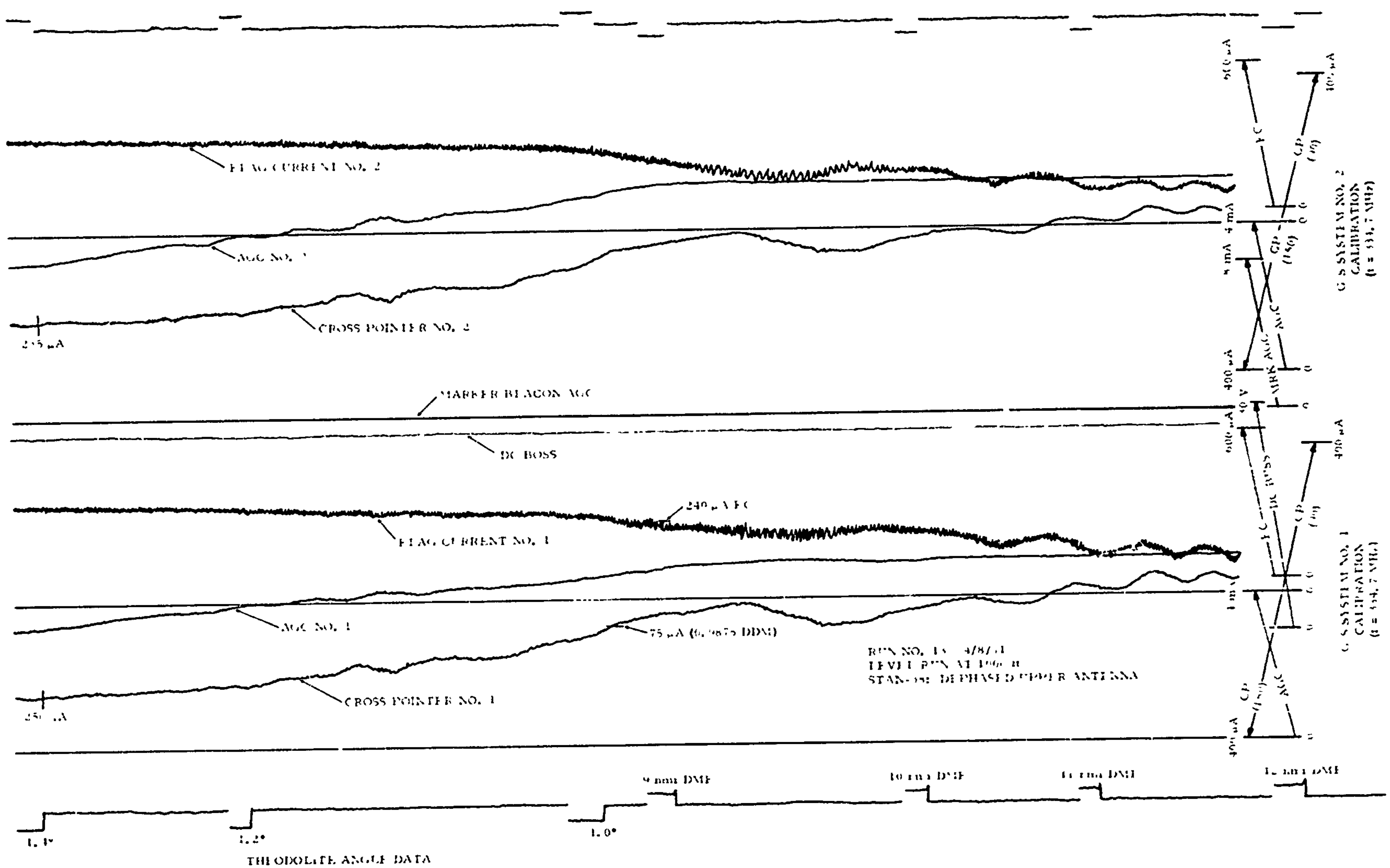

FIGURE 27. AIRBORNE RECORDING - UPPER ANTENNA DEPHASED

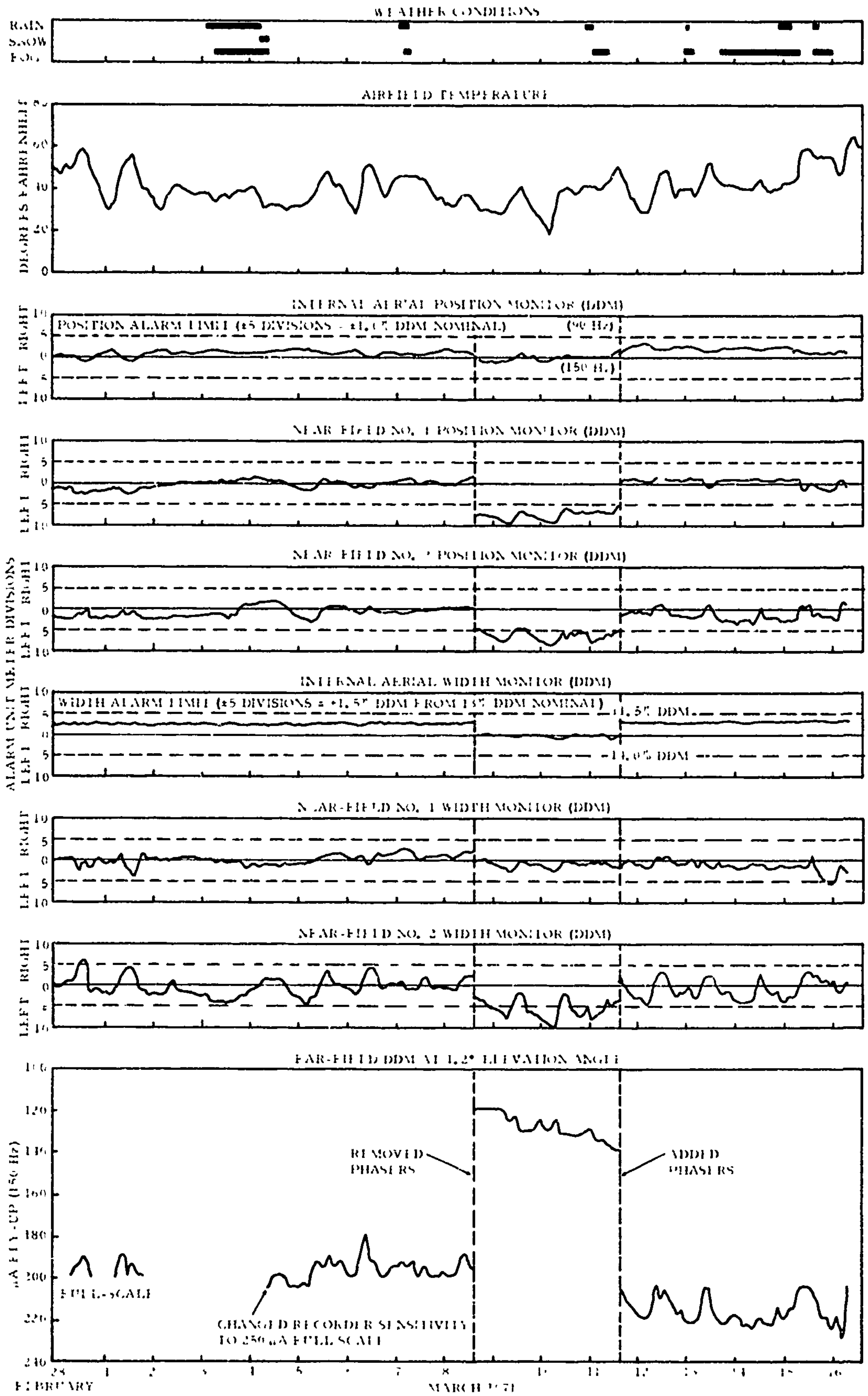

FIGURE 28 - MONITOR - WEATHER DATA

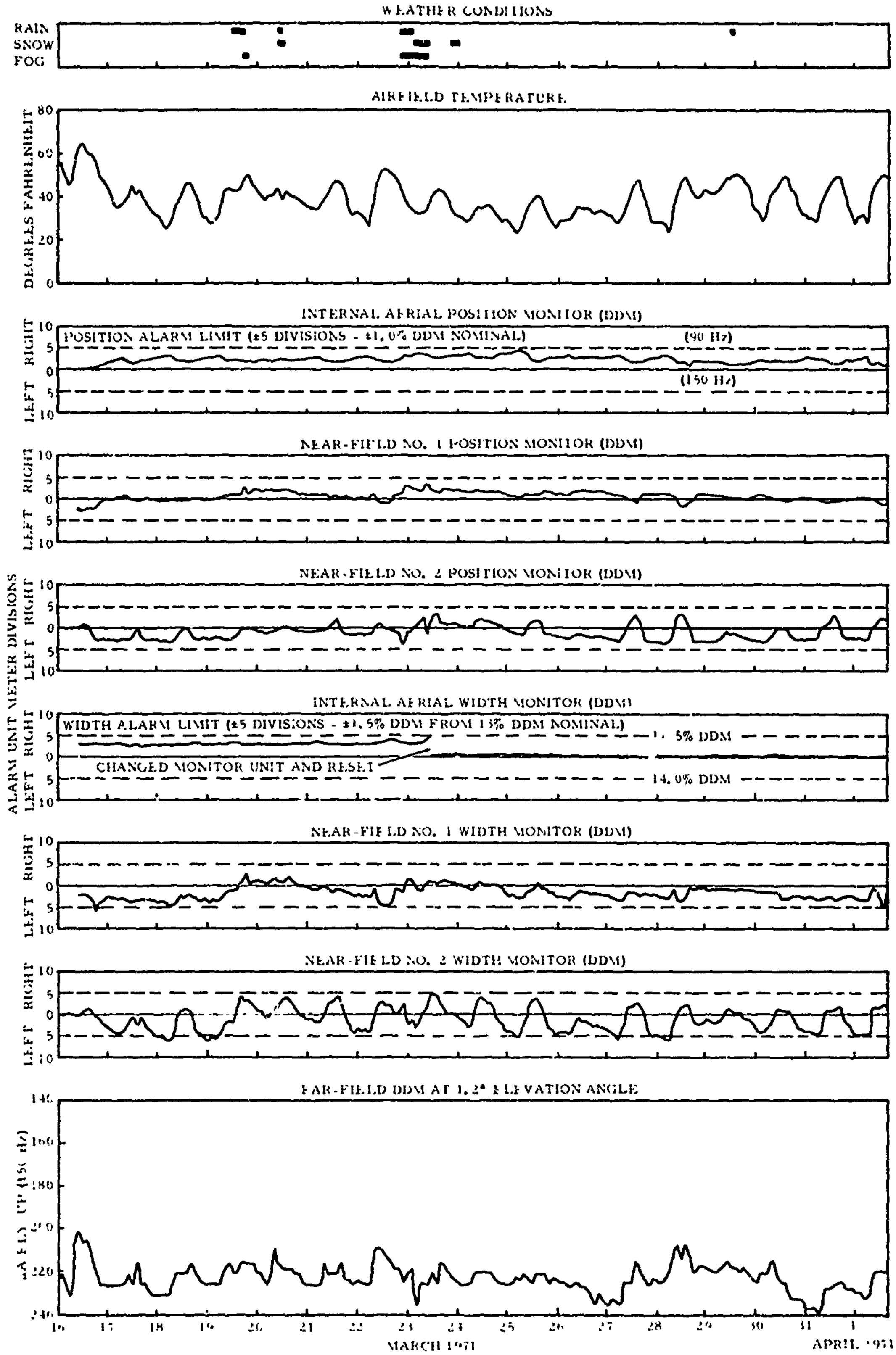

FIGURE 29 - MONITOR - WEATHER DATA

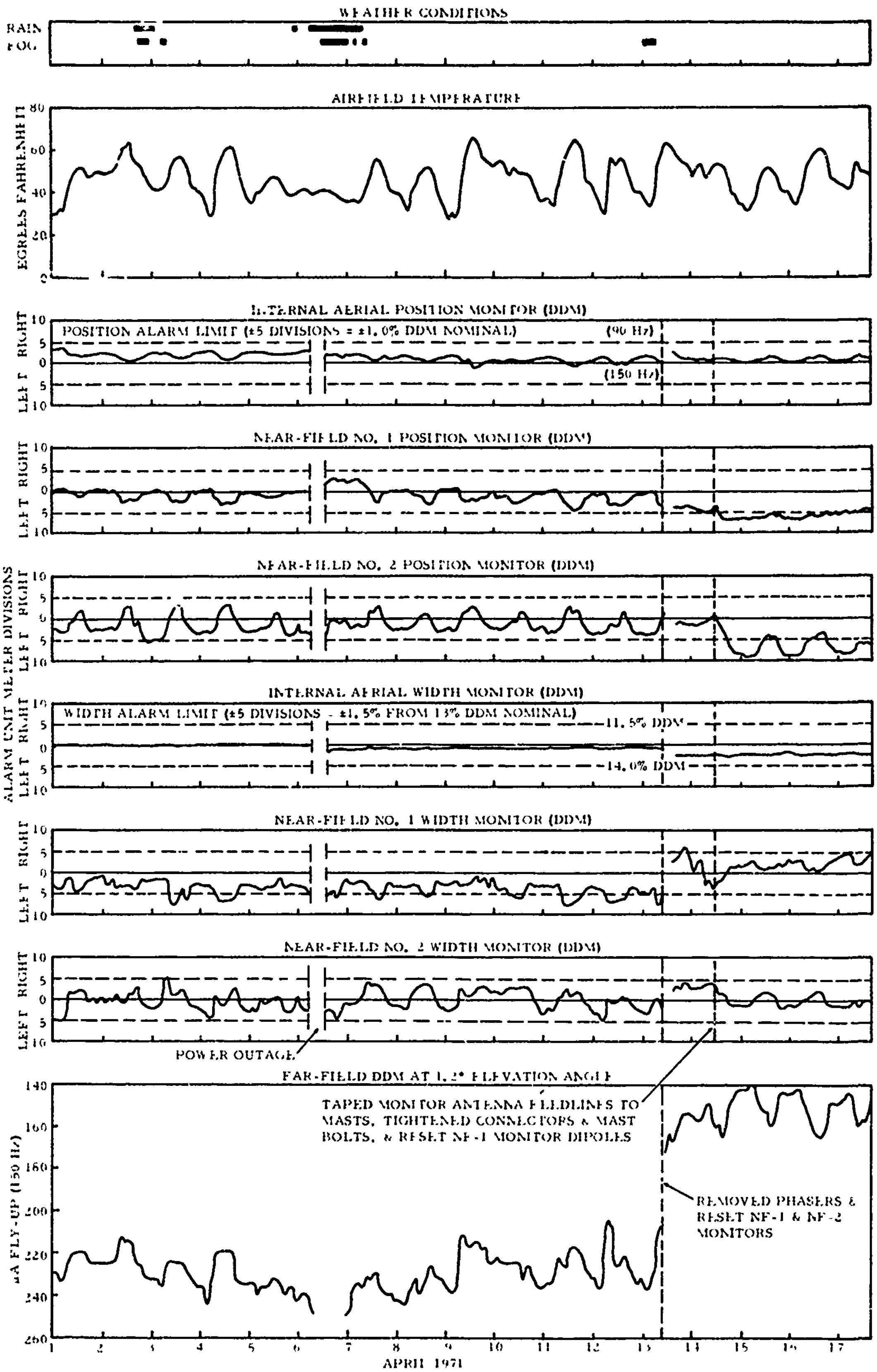

FIGURE 30 - MONITOR - WEATHER DATA

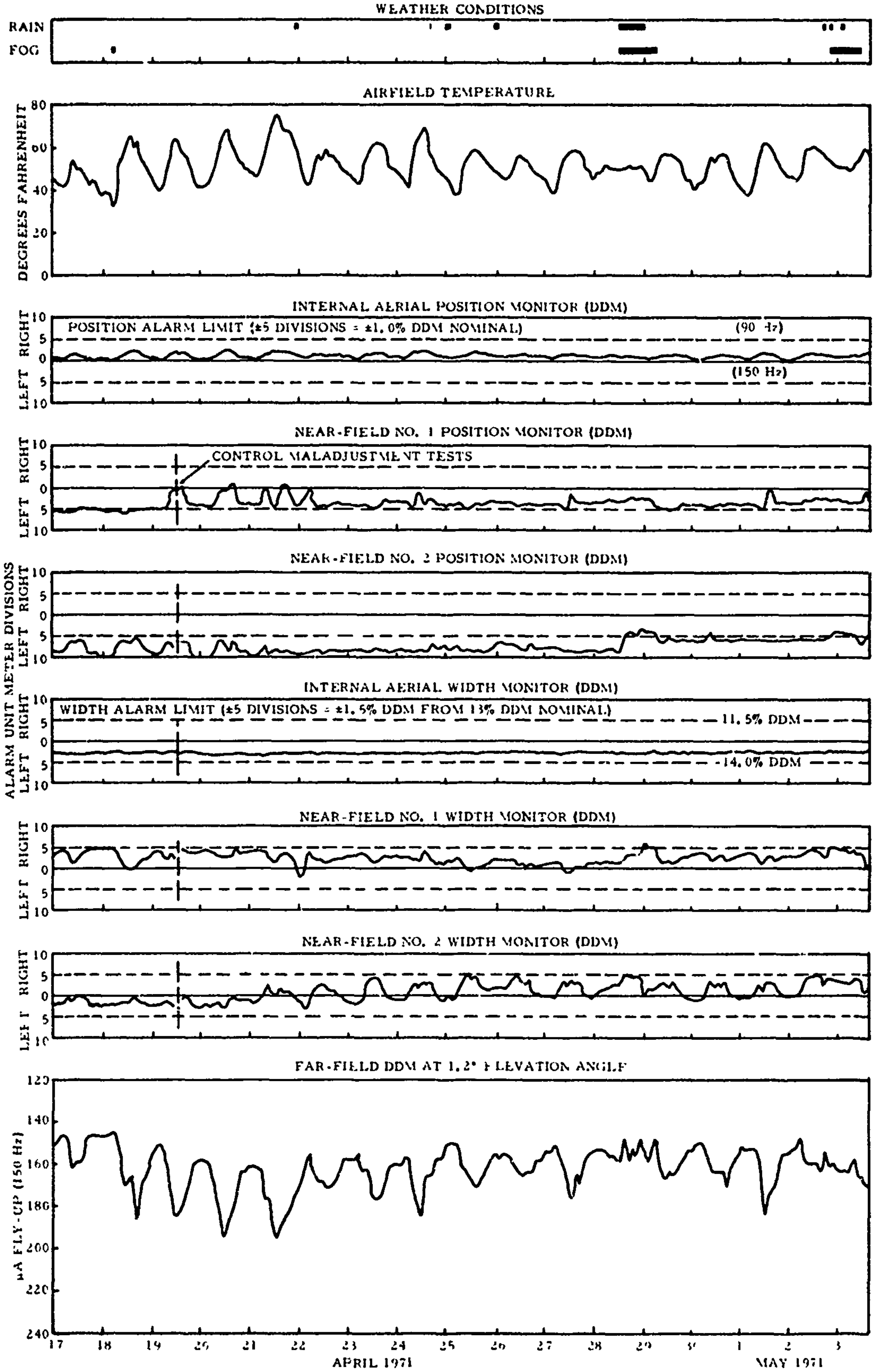

FIGURE 31 - MONITOR - WEATHER DATA

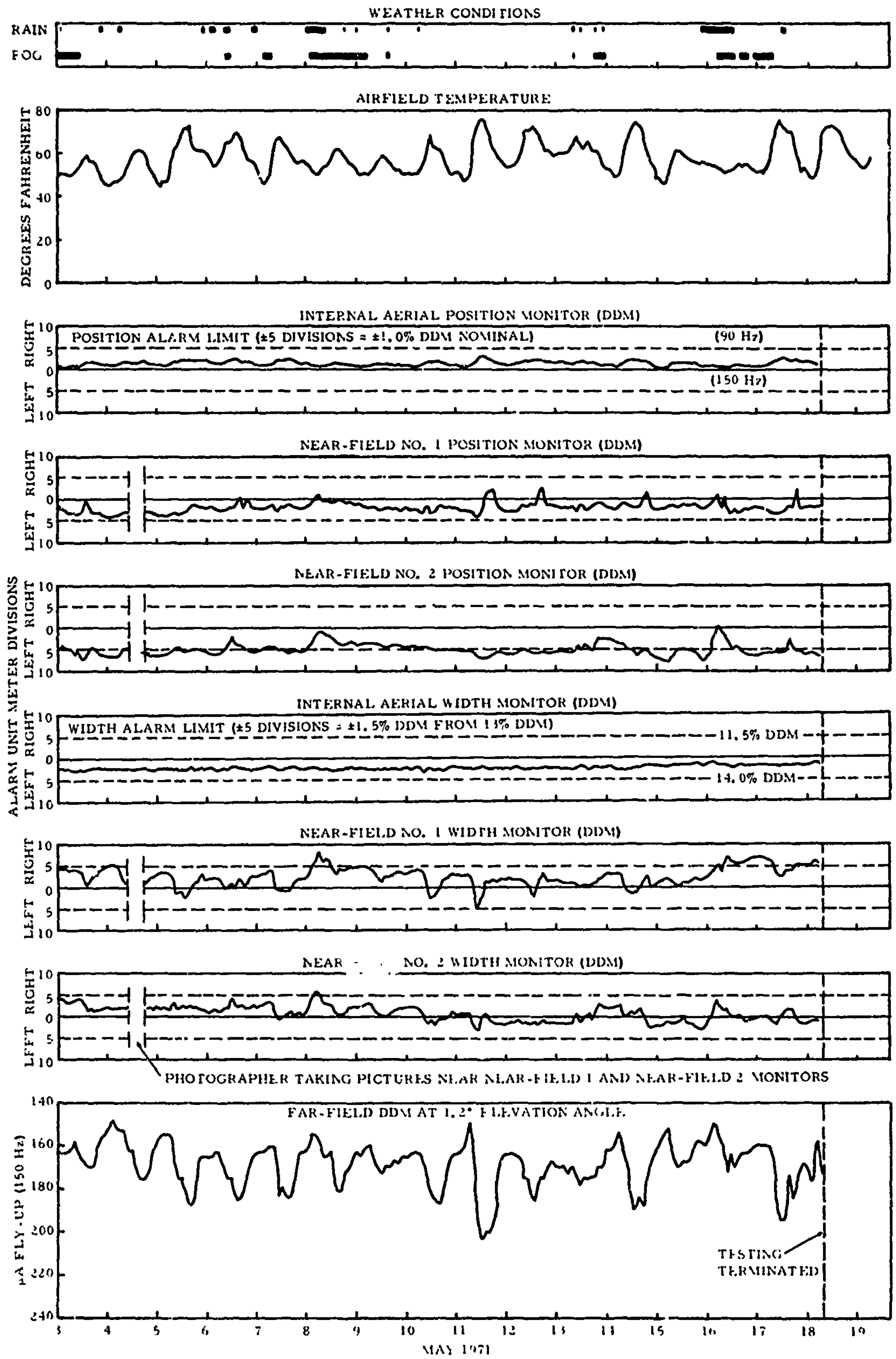

FIGURE 32 - MONITOR - WEATHER DATA

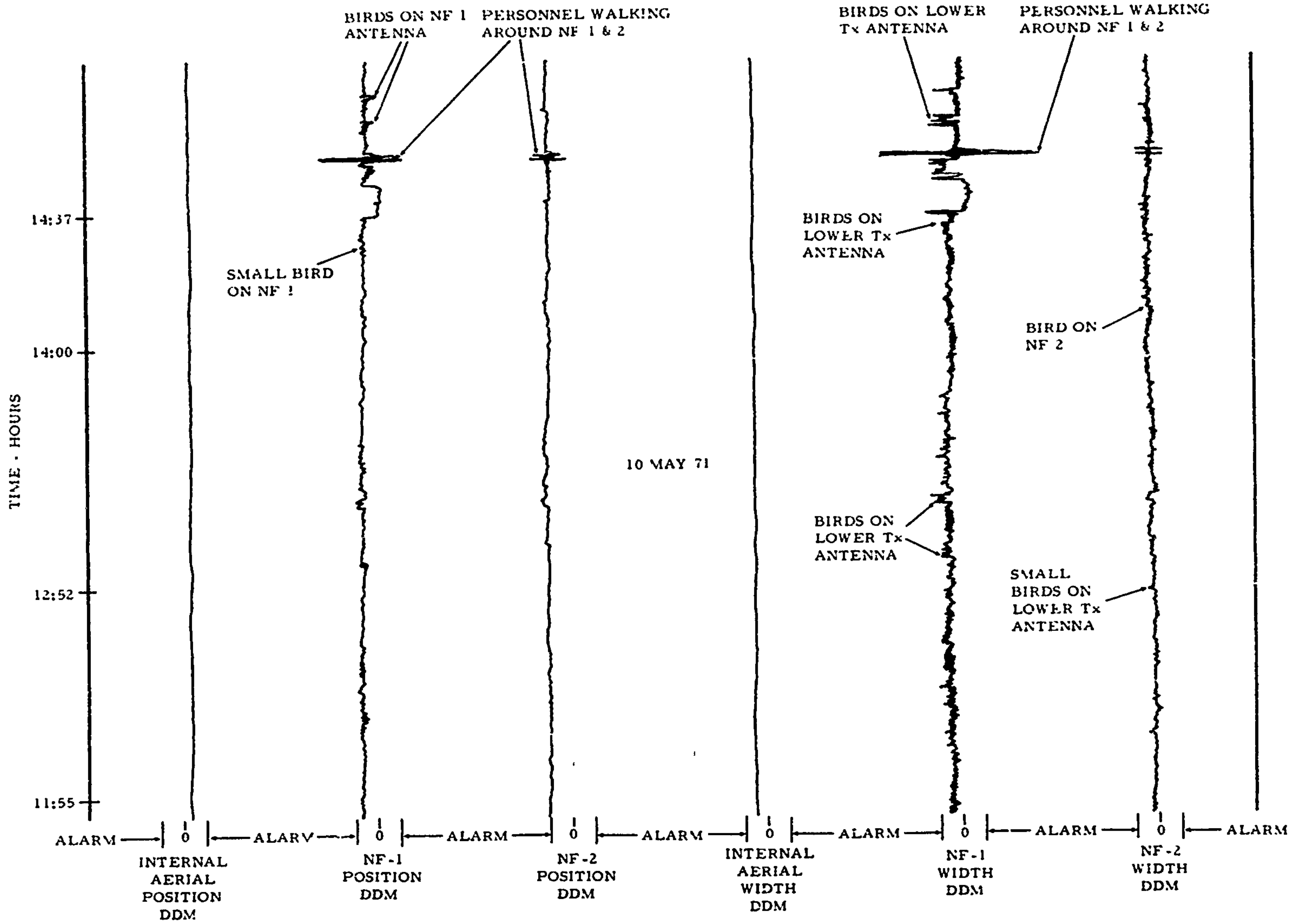

FIGURE 33 - MONITOR RECORDING

APPENDIX A

EVALUATION OF THE PERFORMANCE OF THE STAN 37/38 EXECUTIVE MONITOR SYSTEM UNDER CONDITIONS OF TRANSMITTER ANTENNA MALFUNCTION

Purpose

The STAN 37/38 Instrument Landing System will be set up on runway 4/22 Localizer and 13/31 Glide Path at NAFEC. The specific purpose of the evaluation of this ILS is to investigate the capability of the monitor system to detect and protect the system against significant changes in performance, due to equipment items external to the ILS equipment shelter, prior to the infringement of far-field performance limits on both localizer and glide path elements. It is not necessary to attempt to correlate the measurements taken at the near-field monitor locations. In carrying out this evaluation, it is the intent to identify and report on deficiencies, and where possible, identify the cause; it is not the intention, however, to initiate development to overcome problems revealed during the course of the evaluation.

Procedure

The specific tasks to be undertaken at NAFEC are described below:

1. Installation of STAN 37/38 ILS.

The STAN 37/38 ILS will be installed on 4/22 localizer (108.1 MHz) and 13/31 G.P. (334.7 MHz) in the conventional manner as described in the setting-up procedures. Following completion of the installation, the primary performance characteristics of the system will be established. These will include ground and flight measurement of the following parameters:

A. Localizer

(a) Course Alignment and Course Structure (measurement to be made by use of radio theodolite and where necessary phototheodolite).

(b) Course Width and Linearity of Course Width. Course Width to be measured by phototheodolite recordings. Linearity to be measured on a flight across the course.

(c) Field Strength and Vertical Pattern. Measured on inbound flight at 2,000 ft constant height above threshold.

(d) DDM, MOD SUM, and field strength within the Sector ±35° with respect to the course line measured on semiorbit flight at 1,000 ft above threshold and constant range of 5 nmi from the facility.

(e) Modulation sum at approximately $\pm 8°$ with respect to the course. (In this region the course and clearance field strength are approximately equal and low-modulation sum readings may be observed.)

(f) Measurement of relative field strength at an antenna height of 20 ft above ground along the surface of the runway.

B. Type M Glide Path Array

(a) Path angle and path structure. Standard radio theodolite procedure to be employed. Phototheodolite procedure available as necessary.

(b) Path width and path linearity.

(c) Clearance below path measured on a level flight towards the facility at a constant height of 1,000 ft above landing threshold from 10 nmi to intersection of the glide path.

(d) Path angle and width at ± 150 microamperes with respect to localizer centerline measured by an aircraft tracked by radio and/or phototheodolite.

Object

To establish normal operating characteristics of the localizer and glide path at their respective locations for subsequent comparison with degraded performance characteristics.

Localizer Test I: Maladjust the distribution of energy across the array and record the response of the near-field monitors; measure as specified in Test 1A (a), (b), and (d) the far-field performance characteristics. (U.K. B.O.T. to advise FAA on amplitude and phase distribution to be employed in this test.)

Object of Test I - To determine the consequences of significant changes in antenna VSWR on the antenna radiation pattern and examine the ability of the monitor system to detect significant changes in performance before far-field performance has deteriorated beyond specified acceptance limits.

Localizer Test II: Measurement of effects of specific amplitude and phase errors associated with individual dipoles comprising the basic localizer antenna.

1. Introduce variable phase line in series with feeder to individual antennas 1 through 6.

2. Introduce variable attenuator in series with individual antennas 1 through 6.

3. Short circuit individual antennas 1 through 6.

At each stage in these series of tests, records of monitor system performance are to be kept and measurement of far-field system performance is to be made as specified in Test 1A (a), (b), and (d).

Object of Test II - To examine the operation of the monitor system in the presence of significant changes in individual transmitter antenna characteristics and ascertain the extent of far-field performance deterioration prior to alarm action being initiated by the executive monitor.

Localizer Test III: Measurement of the effect of deterioration in antenna reflector wire system on the performance of the executive monitor system and far-field performance characteristics as specified in Test 1A (a), (b), and (d). Complete sections of reflector wires will be removed/released at one clamp point and effects recorded.

Object of Test III - To examine the operation of the monitor system and consequent far-field performance in the event of damage to the localizer antenna array resulting from the build up of ice deposits on the reflector wire system.

Localizer Test IV: Comparison of overflight interference effects, due to a preceeding aircraft takeoff, between STAN 37 and V-Ring antenna. Both STAN 37 and V-Ring localizer systems must be available for this particular test. Both systems should be operating on different frequencies. The aircraft is to be equipped with two receivers, each tuned to the appropriate localizer frequency. The ILS monitor for either system may be inhibited if necessary during the course of this exercise. Measure and record the effects at the far-field monitor and in an aircraft between 10,000 ft range from threshold and throughout the landing rollout phase the effects on the two ILS localizer systems of preceeding takeoff aircraft interference.

Object of Test IV - To establish whether differences in the vertical directivity of the two types of localizer antenna affect the level or duration of interference received in a landing or approaching aircraft.

Localizer Test V: Effects of differential cooling (temperature effects) upon the operational performance of the localizer. Insulate the array cable trays, feeding one-half of the localizer antenna array and allow other cable tray to be exposed to direct radiation from sun. Measure effect on near-field monitor system and far-field performance.

Object of Test V - To determine the effect of differential cooling or heating of the antenna-feed system on the executive monitor system and far-field performance.

Localizer Test VI: Record the effects of prevailing weather conditions on the performance of the executive monitor system.

Glide Path Test I: Evaluation of the capability of the executive monitor system to detect performance deficiencies resulting from amplitude and phase errors on the glide path antenna feeder system.

1. Maladjust initial phase and amplitude conditions on the upper colinear antenna. Measure far-field performance as specified in B(a), (b), and (c) and record executive monitor conditions.

2. As for (1) for the middle antenna.

3. As for (1) for the lower antenna.

Object of Test I - To determine the consequences of significant errors in vertical and azimuth patterns and examine the ability of the monitor system to detect significant changes in performance prior to significant deterioration in far-field performance.

Glide Path Test III - Record the effects of prevailing weather conditions on the operation of the executive monitor system.

Note 1

Throughout the course of the above series of tests for both localizer and glide path elements it may be deemed convenient to utilize far-field monitor indications to determine the necessity to undertake the more extensive flight measurement program described.

Note 2

Unless otherwise specified above, the equipment must be reset to the initial operating conditions at the conclusion of each exercise prior to undertaking the following exercise.

APPENDIX B

EVALUATION OF THE PERFORMANCE OF THE STAN 37/38 ILS UNDER SPECIFIED OPERATING CONDITIONS AT NAFEC

Purpose

Following completion of the tests described in Appendix A, an evaluation will be conducted into the performance and operational use of the system under certain specified conditions. Initially, some of this work will take place with the equipment at its original location on runway 04, but the main operational use and evaluation of the equipment will be made with it relocated on runway 13. The tests described herein comprise only a part of the overall evaluation of the STAN 37/38 ILS to meet the performance, safety and integrity requirements of a Category III system. Other elements of the overall evaluation are being undertaken independently in the U.K. This evaluation of the performance of the STAN 37/38 equipment is to determine the characteristics of the system when it is subjected to environmental effects which are natural to an airfield. The availability of a Category III ILS system at NAFEC will allow airborne Category III ILS equipment performance evaluation by FAA and other users. As these tests will be made with the STAN 37 antenna located closely behind a V-Ring array (on runway 4) and a waveguide array (on runway 13) respectively, the opportunity is afforded to compare the radiation pattern of the STAN 37 with the radiation patterns of the other arrays, especially with regard to the effects of overflight interference. In addition, given the fact that an operational ILS is already installed on runway 13, it will be not only possible but also necessary to verify the compatibility of two ILS systems operating on different frequencies simultaneously on the same runway. Operational use and evaluation of the equipment will be limited to the localizer on runway 13.

Procedure

The proposed work is outlined in the following steps. The test procedures for the equipment on runway 4 previously agreed upon remain unchanged, with the exception of the following paragraphs in the original test plan. In paragraph 1.B d, change "Path angle and Path Structure at +8° with..." to read "Path angle and width at +150 uA localizer with...." Delete Glide Path Test I paragraph (1b). Delete Glide Path Test II and following paragraph. Delete Object of Glide Path Test II and following paragraph.

I. STAN 37/38 on Runway 04

1. With the glide path operated as a type M array, periodic measurement of the DDM will be carried out below 1.6°. This may conveniently be done by means of two dipoles mounted at right angles of 0.75° and 1.25°, respectively, relative to the glide path site, on the AHSR tower (Building 172) which is located on a 17° angle displaced from the course-line of the STAN 37. The purpose of this test is to assess the signal stability over a range of weather conditions as well as any tendency towards a false course at a vertical angle of about 1°.